

**ASSESSMENT OF GENETIC POTENTIAL OF  
FRENCH BEAN (*Phaseolus vulgaris* L.)  
GENOTYPES IN POLY-NET HOUSE**

**Thesis**

**Submitted to the Punjab Agricultural University  
in partial fulfillment of the requirements  
for the degree of**

**MASTER OF SCIENCE  
in  
HORTICULTURE (VEGETABLE SCIENCE)  
(Minor Subject: Plant Breeding and Genetics)**

**By**

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LUDHIANA – 141 004**

**2018**

## CERTIFICATE – I

This is to certify that the thesis entitled, “**Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house**” submitted for the degree of **Master of Science**, in the subject of **Vegetable Science** (Minor subject: **Plant Breeding & Genetics**) to the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ramandeep Kaur (A-2016-A-167-M)** under my supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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## **CERTIFICATE – II**

This is to certify that the thesis entitled, “**Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house**” submitted by **Ramandeep Kaur (A-2016-A-167-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **Master of Science**, in the subject of **Vegetable Science** (Minor subject: **Plant Breeding & Genetics**) has been approved by the Student’s Advisory Committee along with External Examiner after an oral examination on the same.

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### ABSTRACT

French bean (*Phaseolus vulgaris* L.,  $2n=2x=22$ ) is one of the most important legume crop grown throughout the world for green tender pods and dry seeds (*rajmah*). The experiment was conducted to assess the genetic potential of 29 French bean genotypes collected from various sources. The crop was raised in poly-net house during winter 2016-17 and 2017-18 in a Randomized Complete Block Design (RCBD) at Vegetable Research Farm, Punjab Agricultural University, Ludhiana with an objective to get high productivity and quality pods during off-season. The significant variation was observed among all the genotypes for all the traits. The green pod yield per plant was found to be high in genotypes Lakshmi (992.33 g), Star-1 (955.50 g), FBK-4 (911.17 g), AVT Var-3 (908.50 g), Kentucky Blue (856.17 g) and FBK-1 (842.67 g) which out yielded check variety Kentucky Wonder (793.33 g). Regarding quality parameters, maximum dry matter was observed in FBK-13 (13.87%), protein content in FBK-1 (9.67%), sugar content in FBK-5 (9.67%) and minimum fibre content in FBK-12 (0.69%). The phenotypic coefficient of variation (PCV) was found to be higher than their respective genotypic coefficient of variation (GCV) for all the traits which showed the influence of environment on these traits. Selection is preferred when a major proportion of variation is heritable variation. The high heritability along with high genetic advance was recorded for most of characters which showed the presence of additive gene action and selection should be performed for improvement of these characters. Path analysis study revealed that pod weight, number of pods per plant, number of pickings and harvesting span had maximum direct effect on green pod yield per plant. The above characters which had maximum positive direct effect on green pod yield were also positively correlated with yield and thus selection for these traits will be effective for improving the total green pod yield. There was an excellent plant growth, productivity and better quality pods under poly net house conditions. This off season crop can be successfully raised under Punjab conditions during winter season which fetches high price in the market and is economical to the farmers of Punjab when there is no availability of green pods from high altitude. Hence, there is a great scope of cultivation of pole type French bean under poly-net house conditions in Punjab.

**Keywords:** French bean, net-house, indeterminate type, green pod yield and quality attributes

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Signature of the Major Advisor

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Signature of the Student

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### ਸਾਰ ਅੰਸ਼

ਫਰੈਂਚ ਬੀਨ (*ਫਿਜ਼ੀਓਲਿਸ ਵਲਗੇਰਿਸ* ਐਲ.  $2n=2x=22$ ) ਹਰੀ ਸਬਜ਼ੀ ਵਜੋਂ ਅਤੇ ਸੁੱਕੇ ਬੀਜਾਂ (ਰਾਜਮਾਹ) ਦੀ ਖਪਤ ਲਈ ਸਾਰੇ ਸੰਸਾਰ ਵਿੱਚ ਉਗਾਈ ਜਾਣ ਵਾਲੀ ਇੱਕ ਅਹਿਮ ਫਲੀਦਾਰ ਸਬਜ਼ੀ ਹੈ। ਮੌਜੂਦਾ ਅਧਿਐਨ ਵੱਖੋ-ਵੱਖਰੇ ਸਰੋਤਾਂ ਤੋਂ ਲਏ ਗਏ 29 ਫਰੈਂਚ ਬੀਨ ਜੀਨੋਟਾਈਪਾਂ ਦੀ ਅਨੁਵਾਂਸ਼ਿਕੀ ਸਮਰੱਥਾ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਲਈ ਕੀਤਾ ਗਿਆ। ਰੈਂਡੋਮਾਈਜ਼ਡ ਕੰਪਲੀਟ ਬਲਾਕ ਡਿਜ਼ਾਈਨ (ਆਰ.ਸੀ.ਬੀ.ਡੀ.) ਵਿਧੀ ਤਹਿਤ ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਸਬਜ਼ੀ ਖੋਜ ਫਾਰਮ ਵਿਖੇ 2016-17 ਅਤੇ 2017-18 ਦੀਆਂ ਸਰਦੀਆਂ ਦੌਰਾਨ ਉੱਚ ਉਤਪਾਦਨ ਅਤੇ ਗੁਣਵਤਾ ਭਰਪੂਰ ਫਲੀਆਂ ਹਾਸਲ ਕਰਨ ਦੇ ਉਦੇਸ਼ ਨਾਲ ਪੋਲੀ ਨੈੱਟ-ਹਾਊਸ ਵਿੱਚ ਫਸਲ ਉਗਾਈ ਗਈ। ਸਾਰੇ ਦੇ ਸਾਰੇ ਗੁਣਾਂ ਲਈ ਸਾਰੇ ਜੀਨੋਟਾਈਪਾਂ ਵਿੱਚ ਅਰਥਪੂਰਨ ਵਿਭਿੰਨਤਾ ਦਰਜ ਕੀਤੀ ਗਈ। ਜੀਨੋਟਾਈਪ ਲਕਸ਼ਮੀ (992.33 ਗ੍ਰਾਮ), ਸਟਾਰ-1 (955.50 ਗ੍ਰਾਮ), ਐਫ ਬੀ ਕੇ-4 (911.17 ਗ੍ਰਾਮ), ਏ ਵੀ ਟੀ ਵੈਰਾਇਟੀ-3 (908.50 ਗ੍ਰਾਮ), ਕੈਨਟਿਉਕੀ ਬਲੂ (856.17 ਗ੍ਰਾਮ) ਅਤੇ ਐਫ ਬੀ ਕੇ-1 (842.67 ਗ੍ਰਾਮ) ਵਿੱਚ ਪ੍ਰਤੀ ਪੌਦਾ ਹਰੀ ਫਲੀ ਦਾ ਝਾੜ ਸਭ ਤੋਂ ਵਧੇਰੇ ਪਾਇਆ ਗਿਆ ਜੋਕਿ ਚੈੱਕ ਵਜੋਂ ਵਰਤੀ ਗਈ ਵੈਰਾਇਟੀ ਕੈਨਟਿਉਕੀ ਵੰਡਰ (793.33 ਗ੍ਰਾਮ) ਤੋਂ ਬਹੁਤ ਵਧੇਰੇ ਸੀ। ਗੁਣਵਤਾ ਮਾਪਦੰਡਾਂ ਦੀ ਗੱਲ ਕਰੀਏ ਤਾਂ ਜੀਨੋਟਾਈਪ ਐਫ ਬੀ ਕੇ-13 (13.87%) ਵਿੱਚ ਸੁੱਕੇ ਮਾਦੇ, ਐਫ ਬੀ ਕੇ-1 (9.67%) ਵਿੱਚ ਪ੍ਰੋਟੀਨ ਦੀ ਮਾਤਰਾ ਅਤੇ ਐਫ ਬੀ ਕੇ-5 (9.67%) ਵਿੱਚ ਸੂਗਰ ਦੀ ਮਾਤਰਾ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਅਤੇ ਐਫ ਬੀ ਕੇ 12 (0.69%) ਵਿੱਚ ਰੇਸ਼ੇ ਦੀ ਮਾਤਰਾ ਸਭ ਤੋਂ ਘੱਟ ਦਰਜ ਕੀਤੀ ਗਈ। ਸਾਰੇ ਦੇ ਸਾਰੇ ਗੁਣਾਂ ਲਈ ਵਿਭਿੰਨਤਾ ਫਿਨੋਟਿਪਿਕ ਗੁਣਾਂਕ (PCV) ਆਪਣੇ ਸੰਬੰਧਤ ਵਭਿੰਨਤਾ ਜੀਨੋਟਿਪਿਕ ਗੁਣਾਂਕ (GCV) ਤੋਂ ਵਧੇਰੇ ਸੀ ਜਿਸ ਤੋਂ ਇਹਨਾਂ ਗੁਣਾਂ ਉਪਰ ਵਾਤਾਵਰਣ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਪਤਾ ਚੱਲਿਆ। ਜਦੋਂ ਵਿਭਿੰਨਤਾ ਦਾ ਪ੍ਰਮੁੱਖ ਅਨੁਪਾਤ ਅਨੁਵਾਂਸ਼ਿਕੀ ਵਿਭਿੰਨਤਾ ਦਰਸਾਉਂਦਾ ਹੈ ਤਾਂ ਚੋਣ ਨੂੰ ਤਰਜੀਹ ਦਿੱਤੀ ਜਾਂਦੀ ਹੈ। ਜ਼ਿਆਦਾਤਰ ਗੁਣਾਂ ਲਈ ਉੱਚ ਅਨੁਵਾਂਸ਼ਿਕੀ ਵਿਕਾਸ ਦੇ ਨਾਲ ਨਾਲ ਉੱਚ ਅਨੁਵਾਂਸ਼ਿਕਤਾ ਨੇ ਐਡਿਟਿਵ ਜੀਨ ਐਕਸ਼ਨ ਦੀ ਹੋਂਦ ਦਰਸਾਈ ਅਤੇ ਗੁਣਾਂ ਦੇ ਸੁਧਾਰ ਲਈ ਚੋਣ ਨੂੰ ਤਰਜੀਹ ਦਿੱਤੀ ਜਾਣੀ ਚਾਹੀਦੀ ਹੈ। ਪਾਥ ਐਨੇਲਿਸਿਸ ਅਧਿਐਨ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਫਲੀ ਦੇ ਭਾਰ, ਪ੍ਰਤੀ ਪੌਦਾ ਫਲੀਆਂ ਦੀ ਗਿਣਤੀ, ਤੁੜਾਈਆਂ ਦੀ ਗਿਣਤੀ ਅਤੇ ਤੁੜਾਈਆਂ ਦੇ ਕੁੱਲ ਸਮੇਂ ਦਾ ਪ੍ਰਤੀ ਪੌਦਾ ਹਰੀਆਂ ਫਲੀਆਂ ਦੇ ਝਾੜ ਉਪਰ ਸਭ ਤੋਂ ਵਧੇਰੇ ਸਿੱਧਾ ਪ੍ਰਭਾਵ ਪਿਆ। ਉਪਰੋਕਤ ਸਾਰੇ ਗੁਣਾਂ, ਜਿਹਨਾਂ ਦਾ ਹਰੀਆਂ ਫਲੀਆਂ ਦੇ ਝਾੜ ਉਪਰ ਸਭ ਤੋਂ ਵਧੇਰੇ ਸਕਾਰਾਤਮਕ ਪ੍ਰਭਾਵ ਸੀ ਦਾ ਝਾੜ ਨਾਲ ਵੀ ਸਕਾਰਾਤਮਕ ਸਬੰਧ ਸੀ ਅਤੇ ਇਸ ਲਈ ਹਰੀ ਫਲੀ ਦੇ ਕੁੱਲ ਝਾੜ ਦੇ ਸੁਧਾਰ ਲਈ ਇਹਨਾਂ ਗੁਣਾਂ ਦੀ ਚੋਣ ਪ੍ਰਭਾਵਸ਼ਾਲੀ ਸੀ। ਪੋਲੀ ਨੈੱਟ-ਹਾਊਸ ਹਲਾਤਾਂ ਅਧੀਨ ਪੌਦੇ ਦਾ ਵਿਕਾਸ, ਪੈਦਾਵਾਰ ਅਤੇ ਵਧੀਆ ਗੁਣਵਤਾ ਵਾਲੀਆਂ ਫਲੀਆਂ ਦਾ ਉਤਪਾਦਨ ਬਹੁਤ ਵਧੀਆ ਸੀ। ਸਰਦੀ ਰੁੱਤ ਦੌਰਾਨ ਪੰਜਾਬ ਦੇ ਜਲਵਾਯੂ ਅਧੀਨ ਇਸ ਆਫ-ਸੀਜ਼ਨ ਫਸਲ ਦੀ ਕਾਸ਼ਤ ਸਫਲਤਾਪੂਰਵ ਕੀਤੀ ਜਾ ਸਕਦੀ ਹੈ ਜਿਸਦਾ ਬਜ਼ਾਰ ਵਿੱਚ ਵਧੇਰੇ ਮੁੱਲ ਮਿਲਦਾ ਹੈ ਅਤੇ ਇਸ ਫਸਲ ਦੀ ਕਾਸ਼ਤ ਪੰਜਾਬ ਦੇ ਕਿਸਾਨਾਂ ਲਈ ਆਰਥਿਕ ਪੱਖੋਂ ਫਾਇਦੇਮੰਦ ਹੈ। ਇਸ ਲਈ, ਪੰਜਾਬ ਵਿੱਚ ਪੋਲੀ ਨੈੱਟ ਹਾਊਸ ਹਲਾਤਾਂ ਅਧੀਨ ਫਰੈਂਚ ਬੀਨ ਦੀ ਕਾਸ਼ਤ ਦੀ ਬਹੁਤ ਵਧੇਰੇ ਗੁੰਜਾਇਸ਼ ਹੈ।

**ਮੁੱਖ ਸ਼ਬਦ:** ਫਰੈਂਚ ਬੀਨ, ਨੈੱਟ-ਹਾਊਸ, ਅਨਿਸ਼ਚਿਤ ਕਿਸਮ, ਹਰੀਆਂ ਫਲੀਆਂ ਦਾ ਝਾੜ, ਗੁਣਵਤਾ ਮਾਪਦੰਡ

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## CHAPTER I

### INTRODUCTION

French bean (*Phaseolus vulgaris* L.,  $2n=2x=22$ ) is one of the most important legume crop grown throughout the world as a green vegetable as well as for dry seeds (*rajmah*). It belongs to family Fabaceae and is highly self pollinated crop. French bean is also known as common bean, bush bean, kidney bean, snap bean, haricot bean and navy bean. It is commonly known as *Rajmah* in India. French bean also known as ‘Grain of hope’ (Sofi *et al* 2011) and ‘Super food’ (Saleh *et al* 2012).

French bean is widely grown in North and Central America, Eastern Africa and Eastern Asia. Brazil is the largest producer of French bean in the world. In India, it is grown in Himachal Pradesh, Jammu & Kashmir, Bihar, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Punjab, Haryana and Uttar Pradesh (Parkash and Ram 2014). In India, beans are grown on an area of 198 thousand hectare with an annual production of 2012 thousand MT (Anonymous 2017). However, in northern India, cultivation of French bean is only limited to kitchen gardens.

In India, it is mainly grown for tender pod vegetable whereas in USA, it is grown for processing at large scale. It is a multipurpose crop grown for vegetable, dry seed, fodder and also as a canned vegetable (Biswas *et al* 2010). French bean is a good source of foliate, magnesium, manganese and dietary fibre. French bean is very low in saturated fatty acids and cholesterol. Its edible pods constitute 94% water, 1.7% protein, 0.1% carbohydrates, 4.5% fat, 1.8% fibre and 0.1% minerals per 100 g (Dhaliwal 2012). Its pods are mildly diuretic in nature and contain a substance that reduces the blood sugar level in the body. It exhibits both carminative and reparative properties against constipation and diarrhea (Duke 1981). This vegetable is not only a good source of nutrition but also improves the fertility of soil by fixation of atmospheric nitrogen.

Among the pulses, French bean is one of the high potential pulse crop. French bean fetches premium price as compared to other vegetables and is a popular vegetable grown almost throughout the year. It is gaining lot of importance due to its short duration and high production potential. French bean is a tender warm season vegetable and sensitive to frost and chilling temperature. It thrives best when temperature ranges between 15-25°C. Its seeds do not germinate if the soil temperature is below 12°C and the seedlings cannot tolerate temperature below 10°C. Extreme high temperature interferes with pod filling. When French bean is sown in September under open field conditions in Punjab, there is severe mortality of plants due to infestation of seedlings with fusarium wilt. Moreover, low temperature coupled with frost during December-January cause mortality of French bean plants. Hence, low and

high temperature both are the limiting factors for successful cultivation of French bean under open field conditions in Punjab. To overcome this problem, its cultivation under protected conditions particularly in poly-net house is the best alternative. As many researches highlighted the benefits of protected cultivation in many vegetable crops especially for higher yields, superior quality and protection from insect-pests. These advantages open the scope of French bean cultivation in poly-net house.

The success of any breeding programme depends on the nature and magnitude of genetic variability present in the species. Genetic improvement of quantitative traits in crop can be achieved through a clear understanding of nature and amount of variability present in the breeding material and extent to which desirable traits are heritable. Therefore, information on genetic parameters such as coefficient of variance and heritability of desirable traits will help the breeder to evolve suitable cultivars. Yield is the most important and complex trait for any improvement program. This trait is governed by polygenes and influenced by plant genotype as well as environmental conditions. However, selection based on yield performance only may give biased conclusions. So, the extent and nature of association between yield and its component traits assume special significance and help breeders to ascertain the real components of yield and effective basis of phenotypic selection. However, we cannot rely on correlation coefficient for effective selection because it does not provide information about nature and cause of association between characters under study. In such cases, the path coefficient analysis reveals the nature of observed association between yield and its attributes. It also reveals the magnitude of contribution in yield by different plant traits thereby provides basis for selection of important yield attributes (Singh *et al* 2009). Path coefficient analysis also reveals direct and indirect causes of association. Therefore, to study the character association correlation coefficient along with path coefficient is a reliable tool.

Very less research work has been done on cultivation of French bean under poly-net house and no variety so far has been recommended for its cultivation in poly-net house in Punjab conditions. Therefore, it is necessary to evaluate the performance of different French bean genotypes under poly-net house in Punjab conditions to have quality produce. The exploitation of variability in French bean genotypes is the pre-requisite for screening of superior genotypes for yield and quality traits. The present investigation was planned with the following objective:

- To determine the genetic potential of indeterminate French bean genotypes under poly-net house.

## CHAPTER II

### REVIEW OF LITERATURE

The present investigation is based on genetic variability for quantitative characters and qualitative characters as variability is pre-requisite for crop improvement programme. Our aim is to display the involvement of variability in quantitative and qualitative characters of green beans for yield. This chapter is devoted to review the studies closely related to the present research work. Research work and analytical techniques used by different researchers have been mentioned in this chapter. A critical review related to present study entitled “Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house” which directly or indirectly reverberate this study is elaborated as under:

Chaudhary and Sharma (2003) assessed genetic variation and heritability for yield and yield components in field pea. The highest phenotypic coefficient of variation was observed for number of pods per plant. Heritability estimates were found to be the highest for plant height. Characters like plant height and pod yield showed the highest genetic advance. Pod yield per plant and number of pods per plant exhibited high heritability along with high genetic advance and effective selection can be done for these characters for improvement programs in pea.

Kumar *et al* (2004) assessed heritability, genetic advance and correlations between 12 different characters with yield among forty-five diverse pea genotypes. The number of pods per plant showed highest heritability. High genetic advance and genetic advance as a percentage of mean was observed for green pod yield. It was also observed that genotypic correlation coefficients were higher in magnitude than corresponding phenotypic values indicating influence of environment on traits.

Singh and Mir (2005) conducted an experiment to study mean, variability, heritability and genetic advance in eighteen pea genotypes for improvement programs. Traits like number of pods per plant, pod yield and average pod yield per plot showed high genotypic coefficient of variation and phenotypic coefficient of variation with very less influence of environment on these traits. Heritability was high for pod yield, average pod yield per plot, number of pods per plant and days to 50% flowering. Higher values of heritability along with high genetic advance were recorded for average pod yield per plot and number of pods per plant whereas moderate heritability with higher genetic advance was observed for traits like pod length and pod diameter which indicates that selection can be made effective for these traits.

Dahiya *et al* (2006) evaluated forty eight genotypes for study of direct and indirect effects of the different yield attributing characters on seed yield. Observations were recorded for 16 quantitative traits such as days to first flowering, days to 50 per cent flowering, days to

pod initiation, days to maturity, pods per cluster, pod length, pods per plant, seeds per pod, biological yield and harvest index. Path coefficient analysis of yield attributes revealed that traits such as biological yield, days to pod initiation, number of clusters per plant and seeds per pod has direct influence on seed yield so during selection maximum emphasis should be given to these traits.

Rai *et al* (2006) studied genetic variation and association between characters in pole-type French bean and revealed that there was wide range of phenotypic variation along with high heritability. The influence of environment on character expression was very low as there was very less difference between phenotypic coefficient of variation and genotypic coefficient of variation. It was found that pod yield per plant was positively correlated with pod length and pod weight at both genotypic and phenotypic levels. Pod weight and number of pods per plant were directly contributed to yield. Hence, these characters are very important for the selection of high yielding genotypes.

Dursun (2007) carried out an experiment to determine the effects of some yield components on yield via path analysis, correlation coefficients and heritability in 21 bean (*Phaseolus vulgaris* L.) genotypes. Significant differences were observed in all genotypes for yield characters. Significantly positive correlation of yield with number of pods per plant, fresh pod weight and seed number per pod was found. Traits such as pod weight, pod length and pod number per plant showed direct effect on yield.

Sardana *et al* (2007) conducted an experiment in 210 accessions of pea germplasm to evaluate genetic variability. Moderate to high levels of genotypic coefficient of variations, heritability and genetic advance were observed for characters like pod length, seed yield per plant and number of pods per plant.

Asati and Singh (2008) studied genetic components such as genetic variability, path coefficient and character association for yield and its contributing characters in French bean. The results showed that all the agro economic traits exhibited a wide range of phenotypic variation. Pod yield per plant, number of pods per plant and pod weight showed high values of genotypic coefficient of variation and phenotypic coefficient of variation. Characters controlled by additive gene action was revealed by high heritability along with high genetic advance. Pod yield per plant was directly influenced by number of pods per plant, pod width and number of seeds per plant which suggests that these characters are very important while making selection for high yielding genotypes. Association analysis showed that pod yield per plant was positively related to pod weight, seed length, seed thickness and number of pods per plant at both genotypic and phenotypic levels.

Bhushan *et al* (2008) studied 141 exotic French bean genotypes for simple correlation coefficient and path analysis. A positive and significant correlation of seed yield per plant

with number of pods per plant, pod length and seed index was obtained. However, number of pods per plant exhibited positive and significant correlation with pod length, days to maturity and plant height. Days to maturity showed positive and significant correlation with plant height. Path coefficient analysis revealed that number of pods per plant, pod length and seed index were most important traits contributing towards seed yield. Therefore, it could be suggested that these characters were most important for selection of yield in French bean.

Chadha *et al* (2008) conducted an experiment on pea and revealed that magnitude of phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits under study. Sufficient genetic variability for yield, grains per pod, number of pods per plant and grain per pod was observed in all genotypes. Duration of marketable pods showed high heritability with moderate genetic advance, so effective selection can be made.

Kumar (2008) studied genetic variation, heritability and genetic advance for 11 characters in 32 varieties of Pea (*Pisum sativum* L.). Grain yield per plant and number of pods per plant recorded high heritability along with high genetic advance which make selection effective for improvement.

Nawab *et al* (2008) evaluated the genetic variability, correlation and path coefficient of different traits in 12 pea genotypes. It was found that there were significant differences in genotypes for days to emergence, days to 50 per cent flowering, number of pods per plant, weight of pods per plant, pod length and green pod yield. High genotypic coefficient of variation coupled with high genetic advance was observed for characters like green pod yield per plot, number of pods per plant and weight of pods.

Andrea *et al* (2009) evaluated forty pea genotypes for selection criteria, correlation coefficients and path analysis for two consecutive years 2007 and 2008. The correlation studies showed that genotypically grain yield was related to numbers of pods, seeds per pod and plant height in 2007 and also with grain diameter and number of nodes at the first pod in 2008. Characters like number of pods and seeds per pod were the main components of seed yield and showed maximum direct effects on this trait. So these characters can be used as selection criteria in order to increase the selection efficiency in pea breeding programs.

In 2009, Guleria *et al* conducted an experiment to assess correlation and path coefficient in ten indigenous and exotic genotypes of garden pea (*Pisum sativum* L.) for 10 different agro-morphological characters among themselves. High genotypic and phenotypic coefficients of variation were observed for pod yield and number of pods. Correlation studies indicated that characters like pod number and seeds per pod not only contributed positively to the pod yield but also had strong correlation coefficient with yield. Thus, the results of character association studies showed that genotypes with higher number of flowers, pods and seeds per pod should be selected to increase the pod yield.

Junaif *et al* (2010) studied genetic variation in twenty six genotypes of French beans (*Phaseolus vulgaris* L.) for yield and other attributes. Moderate to high phenotypic and genotypic coefficient of variation was found for most of traits except for protein content per cent. Characters such as green pod yield and number of pods per plant showed high heritability along with high genetic gain. So these traits could be exploited for further improvement through selection procedures.

Karasu and Oz (2010) studied simple correlation studies between seed yield and certain important agronomical characters in French bean. The effects of these characters on seed yield were also studied. Seed yield per plant with biomass yield and number of pods per plant showed highest positive correlation. Results of path coefficient analysis showed that seed yield per plant followed by plant height had the greatest direct effect on seed yield per hectare. Results also revealed that characters such as number of pods per plant, biomass yield, number of branches per plant, number of seeds per plant, number of immature pods per plant, number of seeds per pod and plant height had highest indirect effects on seed yield per plant.

Salehi *et al* (2010) carried out an experiment to evaluate different effective traits on seed yield of common bean (*Phaseolus vulgaris* L.). Path analysis showed that the maximum direct and positive effects were related to number of seeds per pod and harvest index whereas the only direct and negative effect was related to pod length.

Islam *et al* (2011) studied forty four Hyacinth bean genotypes to estimate their variation and inheritance of characters. The significant variation was found for all the characters among all genotypes. The variation in various characters like number of pods per plant and green pod yield per plant indicated the presence of high yielding genotypes. The GCV was high for pod yield per plant, number of pods per plant and harvesting span. The association was found to be positive between yield and number of pods per plant, pod weight and harvesting duration. Hence, it was concluded that these characters are highly responsible for the selection of improved genotypes with high yield in Hyacinth bean.

Kamaluddin and Shahid (2011) evaluated fifty seven germplasm lines of Rajmash beans for yield and yield contributing traits. Highly significant variation was recorded for plant height and number of pods per plant. Inheritance was observed high for plant height and days to 50% flowering and a positive correlation was found between seed yield and days to 50% flowering, pod length, number of pods per plant and number of seeds per pod. Hence, selection of these traits was suggested for improving yield.

Pandey *et al* (2011) studied eight pole-type French bean genotypes to access the variability and their potential for utilization in improvement programs. Maximum variation

was found in vegetative growth, floral and pod characteristics and fresh pod yield. The significant variation present in genotypes can be utilized for improvement programs.

Sadeghi *et al* (2011) studied different associations for different morpho-agronomic traits of common bean (*Phaseolus vulgaris* L.). The correlation analysis revealed that seed yield is highly correlated with harvest index, seed number per plant, seed number per pod, pod number per plant, seed length, straw weight, days to 50% flowering, days to 50% podding and pod length. Analysis of path coefficients showed that seed number per plant and harvest index had high positive direct effect on the seed yield. Seed yield was closely related to traits such as seed number per plant, pod number per plant, harvest index, seed number per pod, pod weight and pod length.

Sofi *et al* (2011) evaluated forty two genotypes of Rajmash. Genetic advance was high for number of pods per plant. There was positive correlation between yield and number of pods per plant and negative with days to flowering, days to maturity and pod length. Hence, yield directly depends upon number of pods per plant.

Angadi *et al* (2012) assessed twelve genotypes of French bean for correlation studies. For all the characters under study, significant differences were present among genotypes. At both genotypic and phenotypic level, a positive and significant association was present between pod yield per hectare and pod yield per plant, pod length and pod weight.

Devi *et al* (2012) studied thirty three genotypes of bush type French bean for evaluation of genotypes for seed yield and other related traits. Quality analysis was also done for protein and total sugar. DPDFB-2(M) was the most superior line for seed yield based on the characters. Quality analysis showed that protein content was the highest in genotype DPDFB-1 and total sugar in IVFB-2.

Fikreselassie (2012) examined the variability, heritability and determines the relative as selection criteria of traits to improve productivity. Twenty-five field pea genotypes along with two commercial varieties were arranged in randomized complete block design with three replications. Genotypes were highly significant for all of the characters under study. The genotypic coefficient of variation ranged from 11.19% for days to maturity to 25.72% for number of seeds per plant. The estimated broad sense heritability was low to moderate and it ranged from 19.24% for stand count to 50.81% for days to flowering. The path analysis at genotypic level revealed that harvest index and biomass yield contributed major positive direct effects on seed yield.

Kumar *et al* (2012) studied twelve genotypes of French bean for path coefficient analysis. The differences were highly significant for all the characters under investigation. Path coefficient analysis revealed that traits like pod weight, number of pods per plant, pod

length and pod width had maximum direct effect at both genotypic and phenotypic levels on pod yield per hectare. A positive and highly significant association of pod yield per hectare with pod yield per plant, pod length, pod weight and number of seeds per pod was observed at both phenotypic and genotypic level.

Manivannan and Anandakumar (2013) evaluated forty two genotypes of cluster bean for genetic variation. Maximum variation was observed for pods per plant followed by number of clusters per plant and seed yield per plant. Phenotypic coefficient of variation and genotypic coefficient of variation were almost same for characters such as pod length, days to maturity and days to 50% flowering which indicates that these characters were least affected by environment. However, there was high influence of environment on characters like seed yield per plant, number of pods per plant and plant height.

Parmar *et al* (2013) carried out an experiment to study genetic variability on yield and yield contributing traits in thirty genotypes of Dolichos bean (*Lablab purpureus*). The characters under study were days to 50% flowering, days to first pod set, days to maturity, number of pods per cluster, pod length, width of pod, weight of 10 green pods, number of pods per plant and protein content. The significant variability was observed for all traits in genotypes. Protein content showed the lowest coefficient of variation. The phenotypic and genotypic coefficients of variability in the expression of various horticultural traits studied for viz. protein content, days to 50% flowering, days to first pod set, pod length, pod weight, weight of 10 green pods and days to maturity showed little or no difference which suggests a very low influence of environment on these traits. High heritability along with high genetic advance was observed for days to 50% flowering, pod length, pod width and weight of 10 green pods which suggests that these characters could be improved through selection. Significant and positive correlations were observed between yield and other yield components viz. days to first pod set, days to 50 per cent flowering, number of pods per plant, weight of 10 green pods and length of pod. In contrast, the correlation between yield and protein content of pods was significantly negative. The genotypes used in the study are of diverse nature. This variation can be exploited in the breeding programme for development of superior genotypes in Dolichos bean.

Pawar and Prajapati (2013) investigated 58 genotypes of Indian bean for different characters. Analysis of variance revealed that significant genotypic differences were present for all the characters under study. Traits such as grain yield per plant followed by number of pods per plant showed the highest GCV. Characters such as days to 50% flowering, protein content, days to maturity, pod length and plant height showed high estimates of heritability whereas expected genetic advance was high for grain yield per plant, number of pods per

plant, pod length and plant height. High heritability coupled with high genetic advance was exhibited by traits like pod length which indicates the presence of additive gene action. Grain yield per plant was positively and significantly correlated with days to 50% flowering, days to maturity and number of pods per plant which indicates their usefulness in selection of traits contributing to yield. Grain yield was negatively correlated with traits like number of seeds per pod and pod length. Results of path analysis showed that grain yield per plant had the highest positive direct effect of number of pods per plant followed by number of seeds per pod, days to 50% flowering and 100-seed weight while days to maturity and pod length exhibited high negative direct effects on grain yield per plant.

Shahid and Kamaluddin (2013) studied correlation and path analysis in fifty seven germplasm lines of French bean for yield and yield contributing traits. The significant variation was observed for plant height, number of pods per plant and seed yield. Phenotypic coefficient of variation and genotypic coefficient of variation was found to be low for days to 50% flowering, plant height and seed yield. This was mainly due to low influence of environment on these traits and variations were only due to genetic constitution. The degree of inheritance was found to be high for yield contributing traits.

Siddika *et al* (2013) carried out an experiment to assess twenty six advanced lines of pea (*Pisum sativum* L.) It was observed that phenotypic coefficient of variance and genotypic coefficient of variance were close for most of characters except seeds per pod, pods per plant, 100 seed weight and seed yield per plant. Path coefficient analysis revealed that seed yield per plant was positively related to days to 50% flowering, number of pods per plant, seed per plant and 100 seed weight.

Boros *et al* (2014) analysed common bean population for morphological, phenological and agronomical variation in order to know the relation among them and to identify potentially useful lines for future production and breeding programmes. Genotypic variation was considerably significant for number of seeds per plant, number of pods per plant and weight of seeds per plant. The lowest genotypic diversity was found for the protein percentage in the seeds.

Kulkarni *et al* (2014) evaluated twenty genotypes of French bean for study of genetic variability, heritability and genetic advance for different yield contributing characters. All the traits showed significant differences among the genotypes. The phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits which suggests influence of environment. High heritability was observed in traits such as pod width and green pod yield per plant.

Kumar *et al* (2014) evaluated forty four genotypes of French bean for eighteen quantitative characters. The significant variation was found high for all the characters studied. Maximum variation was observed in marketable pod yield per plant followed by number of pods per plant. GCV values were high for number of pods per plant and marketable yield per plant. Heritability was observed higher for all the characters due to low influence of environment on these traits. It was revealed that selection of these traits can be done for the development of high yielding genotypes.

Meena and Dhillon (2014) carried out an experiment to study the genetic variation and inheritance of characters in twenty genotypes of French bean for yield, yield contributing traits and quality parameters under net-house conditions. The genetic variations were observed significant in all genotypes for the characters under study. The green pod yield per plant was positively and significantly correlated with average pod weight and number of pods per plant. There was an excellent growth, high productivity and better quality pods under net house conditions.

Negahi *et al* (2014) investigated 281 common bean genotypes for yield and its components along with some of morphological traits. For all the studied traits differences among genotypes were highly significant. High phenotypic coefficient of variation was observed for 100-seed weight, seed yield, biomass yield, number of pods per plant and number of seeds per plant. A high correlation of biomass yield, number of seeds per plant and number of pods per plant with seed yield was depicted by results of simple correlation. Number of seeds per plant, 100-seed weight and biomass yield were considered as primary source of variation among the various seed yield traits as indicated by path analysis results. On path coefficient analysis, it was observed that characters like number of seeds per plant and 100-seed weight played a vital role in seed yield determination of common bean and these traits could be used as selection criteria in common bean breeding programs.

Noor *et al* (2014) evaluated eleven genotypes of French bean for selection of genotype for optimum yield of fresh pod, dry seed and various biochemical parameters. It was observed that there was no significant difference in protein content of various genotypes under the study. BARI bush bean-1 genotype showed highest yield and superior quality of pods.

Prakash and Ram (2014) evaluated twenty five genotypes of French bean for variability and heritability. High range of variation was reported in green pod yield. The coefficient of variation found minimum for day to 50% flowering and maximum for green pod yield per plot.

Rai and Dharmatti (2014) evaluated thirty one genotypes of cluster bean to identify contribution of various characters to pod yield. On correlation analysis, it was found that studies indicated positive associations of vegetable pod yield per hectare with plant height, pods per cluster, pods per plant and pod yield per plant at genotypic and phenotypic levels, respectively. Path analysis at genotypic level showed that yield per plant exhibited a direct positive effect and had strong positive association with yield per hectare. Days to 50% flowering, pods per cluster and pod breadth had positive indirect effects on yield. High positive direct effect and strong degree of association on yield per plant was observed by phenotypic path coefficient. Traits such as plant height, pods per plant, pod length and pod width showed direct effect on pod yield. This suggests that these parameters may be considered as primary traits for effective selection for high yield.

Ravinaik *et al* (2014) evaluated nine genotypes of Dolichos bean for study of variability, heritability and genetic advance. All the characters under study were significant for the genotypes. At both phenotypic and genotypic levels, pod yield per plant was positively correlated with traits like plant height, number of pods per cluster, pod weight, pod length, pod width, number of seeds per pod and number of pods per plant, whereas a negative correlation was found between pod yield per plant and days to 50 per cent flowering. Path coefficient analysis results revealed that pod yield per plant had the highest positive direct effect on traits like number of flowers per cluster followed by number of pods per cluster, pod width, days to 50 per cent flowering, pod length and negative effect on pod yield per plant was observed for number of pods per plant, average weight of pod and number of seeds per pod at genotypic levels. At phenotypic level, pod yield per plant was directly affected by number of pods per plant followed by pod width, average weight of pod, days to 50 per cent flowering whereas number of pods per plant had negative effect on pod yield per plant.

Sharifi (2014) carried out an experiment to select significant Faba bean genotypes for seed yield and some of agro-morphological traits. It was observed that environmental factors had a small effect on the inheritance of traits. Path coefficient analysis indicated that days to harvesting and pod length had a direct effect on seed yield in Faba bean. Hence, selection can be done on the basis of these traits for improving the seed yield.

Singh *et al* (2014) evaluated the sixty five pole type French bean genotypes. Better yield potential was showed by ten genotypes. High heritability was obtained for traits such as pod weight and pod yield due to additive gene action and it indicates that the variation mainly due to genetic pattern and very less influenced by environment factors. It was also reported that pod weight and number of pods per plant directly contributes towards yield and could be exploited for selection of productive genotypes.

An experiment was conducted by Verma *et al* (2014) to study genetic variation, heritability and expected genetic advance for various traits in Dolichos bean. There were 12 genotypes of *Lablab purpureus* under the investigation. Characters like mean pod weight, number of pods per plant, 100-seed weight, pod yield per plant and pod yield per hectare showed high variation. High heritability and high genetic advance was recorded for all these characters. Hence selection can be made effective for these traits.

Verma *et al* (2014) evaluated thirty four pole-type French bean genotypes for their genetic variability for yield and quality traits. Positive correlation with pod yield was found for all the traits except for traits days to 50% flowering and pod diameter. It was revealed that major characters contributing towards genetic diversity in French bean are number of pods per plant and dry matter content. So, it can be concluded that there is a wide range of variation for most of the traits in French bean genotypes and this variation can be utilized in improvement programs.

Walling and Chaturvedi (2014) studied genetic variation, correlation and path coefficient in twenty French bean genotypes for grain yield. Yield and protein content of pods found to be negatively correlated with each other.

Arunga *et al* (2015) evaluated the genetic diversity of 36 Kenyan French bean genotype accessions. Evaluation was done on basis of combination of morpho-agronomic. The genotypes varied significantly with respect to pod diameter, pod length, pod number per plant, pod weight per plant and seed weight. No significant variation was observed for number of days taken to reach flowering.

Devi *et al* (2015) carried out an experiment to determine genetic variation and associated characters for pod yield in different bush French bean genotypes. The highest variation was present for various traits like pod yield per plant and number of pods per plant. The correlation was found significantly positive between pod yield and days to flowering, average pod weight and pods per plant and showed their potential towards improving yield. The results showed that yield was positively affected by number of pods per plant and average pod weight. Therefore, it was clear from data that number of pods per plant and average pod weight were directly involved in the improvement of yield in French bean.

An experiment was carried out on thirty genotypes of cluster bean to study genetic variation, heritability and genetic advance for yield and yield contributing attributes. Wide range of variation was found in characters such as pod yield per plant, number of pods per plant, number of clusters per plant, pod yield and number of pods per cluster at both genotypic and phenotypic levels. The genotypic and phenotypic variances were high for days to maturity. High heritability was observed for number of pods per cluster and number of

clusters per plant. The lowest heritability was recorded for pod width. Characters such as number of pods per cluster, number of clusters per plant and number of reproductive branches per plant showed high heritability along with high genetic advance. High GCV and PCV along with genetic advance was observed in characters like- number of pods per cluster, number of clusters per plant, number of reproductive branches per plant and pod yield per plot. This indicates that selection can be made effective for improvement programmes (Kumar *et al* 2015).

Prakash *et al* (2015) studied twenty five genotypes of French bean collected from different sources for various quantitative and qualitative components. High range of variation was observed for green pod yield per plant and protein content. High genotypic and phenotypic variances were recorded for 100-seed weight and plant height. Characters *viz.* 100-seed weight and plant height showed high heritability and green pod breath showed low heritability. Plant height, green pod yield and 100-seed weight showed high heritability combined with high genetic advance. High genotypic coefficient of variation and phenotypic coefficient of variation along with high genetic advance was observed for green pod yield. This indicates that improvement of these characters can be made by selections based on phenotypic performance

Santhi *et al* (2015) evaluated ten accessions of traditional French bean for yield and quality attributes. Various characters like days taken for flowering, number of pods, days taken for pod setting, pod length and pod weight per plant were recorded. The genotypic variations were observed highest for pod weight and yield. The expected genetic advance and heritability values were observed for days to flowering, pod length, pod weight and yield.

Georgieva *et al* (2016) performed an experiment on genetic evaluation of five genotypes of forage pea. Results showed significant differences among genotypes for the traits i.e. pod width, seeds per plant, seed weight per plant and 1000 seed weight. Phenotypic and genotypic coefficients of variation were moderate for most of traits except for pod length and pod width. High heritability along with high genetic advance was observed for traits such as seeds per plant, seed weight per plant and plant height which showed presence of additive gene effects. Therefore, effective selection can be made in yield based on these characters.

Mehra *et al* (2016) conducted an experiment to determine correlation, path coefficient and genetic diversity in 75 morphologically diverse genotypes of Blackgram. At both genotypic and phenotypic levels, seed yield was positively correlated with pods per plant, seeds per pod and 100-seed weight. The high degree of association was observed between number of seeds per plant and seed yield per plant followed by pods per plant, biological yield per plant and 100 seed weight. Seed yield per plant was found to be positively correlated

with seeds per plant, pods per plant and biological yield per plant. At both phenotypic and genotypic levels, the highest positive direct effect was observed for seeds per plant followed by biological yield per plant on the seed yield as revealed by path coefficient analysis.

Prasanth *et al* (2016) evaluated twenty-one genotypes of winged bean for various quantitative characters. The results showed that pod yield per plant had highly significant and positive association with pod length, pod girth, pod weight and pods per plant at both genotypic and phenotypic level which indicates that direct selection can be employed for improvement in these traits. Path analysis results showed that traits like pods per plant, pod length, pod girth, days to first flowering and days to final harvest exhibited high positive direct effect on pod yield and pods per plant being the major contributing character. Days to first harvest trait had indirect positive effect through days to first flowering on yield. Through direct and indirect contribution of component traits towards pod yield per plant, it is suggested that indirect selection can be employed for days to first flowering, days to first harvest, pod length and pods per plant in winged bean.

Topwal and Gaur (2016) studied forty-two genotypes of French bean for evaluating genetic variation for various characters like number of pods, pod length, seed per plant, plant height, 100 seed weight, days to flower, maturity and yield per plant. Results revealed highly significant differences for all the studied characters. Characters like number of pods, pod length, seeds per plant, plant height, 100 seed weight, days to flower, maturity and yield per plant showed high heritability and high genetic advance indicating that these traits are more useful for varietal improvement programme.

Alemu *et al* (2017) carried out an experiment to study the nature and extent of association among yield traits in different snap bean genotypes. Yield was positively correlated with number of pods per plant, single green pod weight, pod weight and pod length. A significant negative genotypic correlation was found between green pod yield, days to 50% flowering and days to first picking. Path analysis showed that pod number per plant has maximum positive direct effect on green pod yield followed by single green pod weight. Generally, traits having significant positive correlation and high direct effect on green pod yield can be improved by direct selection.

Kujur *et al* (2017) carried out an experiment on thirty genotypes of Dolichos bean for various yield attributes. Green pod yield per plant was significantly and positively correlated with pod length, pod width, pod weight, number of green pod pickings and days to last green pod harvest. On green pod yield per plant highest direct effect was showed by days to last green pod harvest, pod length, days to first flowering and pod width. While other traits like pod weight, number of green pod picking and days to first pod harvest showed direct negative effect on green pod yield per plant at genotypic as well as phenotypic level.

In the present investigation, studies on genetic variation, character association and path analysis in French bean was carried out. The genotypic correlation coefficients were slightly higher than phenotypic correlation coefficients. The analysis of variance revealed highly significant differences among the genotypes for all the twelve characters under study which indicates the wide range of genetic variability in the existing material. The characters viz., number of pods per plant, pod length, days to maturity and days to 50 per cent flowering showed significant positive correlation with seed yield per plant. In the association among component characters, days to 50 per cent flowering significantly and positively correlated with days to maturity whereas, protein content was negatively significant. Path analysis revealed that pod length and days to maturity recorded the maximum and positive direct effects on seed yield per plant and their association with seed yield per plant were also highly significant and positive (Lad *et al* 2017).

Singh *et al* (2017) evaluated 21 diverse genotypes of French bean to study quantitative variation with respect to yield and yield contributing plant traits. It can be concluded on the basis of results that earliness behavior of the genotypes was not good for high yield while most of the high yielding genotypes showed late maturity. However, early maturing genotypes can be exploited for the development of short duration cultivars.

## CHAPTER III

### MATERIAL AND METHOD

The present study entitled “Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house” was carried out during 2016-17 and 2017-18.

**3.1 Name of experiment** – Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house

#### 3.1.1 Location and Place of work

The field experiment was conducted at Vegetable Research Farm and biochemical analysis was done in Biochemistry Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana.

#### 3.1.2 Methodology

Twenty nine genotypes of French bean obtained from different sources were evaluated at Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana in the poly-net house conditions during winter season of 2016-17 and 2017-18. The sowing was done on raised beds in poly-net house on 20<sup>th</sup> October during both years (2016 and 2017) at a spacing of 90cm × 30cm. The experiment was laid out in a Randomized Complete Block Design with three replications. Each entry consisted of 15 plants in each replication. The standard package of practices recommended for cucumber crop in poly-house was followed to raise a healthy crop (Dhall 2018). Ten randomly selected plants from each replication were chosen for data collection and mean of each observation was used for statistical analysis.

**Table 1: French bean genotypes**

S. No.	Genotypes	Source
1.	Star-1	United States of America
2.	Lakshmi	YSP UHF, Nauni, Solan, HP
3.	Kentucky Blue	United States of America
4.	Stringless Blue Lake	United States of America
5.	Titra Mitra	Kashmir, India
6.	AVT Var-1	IARI, Katrain, HP
7.	AVT Var-2	IARI, Katrain, HP
8.	AVT Var-3	IARI, Katrain, HP
9.	FBB Var-1	IIVR, Varanasi, UP

S. No.	Genotypes	Source
10.	FBB Var-2	IIVR, Varanasi, UP
11.	FBB Var-3	IIVR, Varanasi, UP
12.	FBB Var-4	IIVR, Varanasi, UP
13.	FBK-1	Kashmir, India
14.	FBK-3	Kashmir, India
15.	FBK-4	Kashmir, India
16.	FBK-5	Kashmir, India
17.	FBK-6	Kashmir, India
18.	FBK-7	Kashmir, India
19.	FBK-8	Kashmir, India
20.	FBK-9	Kashmir, India
21.	FBK-10	Kashmir, India
22.	FBK-11	Kashmir, India
23.	FBK-12	Kashmir, India
24.	FBK-13	Kashmir, India
25.	FBK-14	Kashmir, India
26.	FBK-15	Kashmir, India
27.	FBK-16	Kashmir, India
28.	FBK-17	Kashmir, India
29.	Kentucky Wonder (C)	IARI, Katrain, HP

### **3.2 Observations recorded**

#### **A. Quantitative traits**

##### **3.2.1 Days to 50% flowering**

The days to 50% flowering were recorded from ten randomly tagged plants from sowing date to date when 50% plants show at least one flower open and expressed in days.

##### **3.2.2 Days to first harvest**

The number of days from sowing date to the date of first pod picking at marketable stage were recorded and averaged to determine the first harvest of each genotype.

##### **3.2.3 Number of pods per plant**

The total number of pods per plant from all pickings in each treatment from ten randomly tagged plants were counted and average worked out and expressed as number of pods per plant.

### **3.2.4 Pod weight (g)**

The pods harvested from ten randomly selected plants were carefully weighed with an electronic balance and average was calculated and expressed in grams.

### **3.2.5 Pod length (cm)**

The pod length was measured from base to the tip of pod of ten selected pods of each genotype and average was calculated and expressed in centimeters.

### **3.2.6 Pod width (cm)**

The pod width was recorded by digital Vernier Caliper as average of widest part of same pods from ten randomly tagged plants at marketable stage. The average was calculated and expressed in centimeters.

### **3.2.7 Green pod yield per plant (g)**

The yield of French bean from all the pickings of ten tagged plants of each genotype was weighed and averaged to get the yield per plant and expressed in grams.

### **3.2.8 Number of pickings**

Total number of pickings performed for green pod yield in ten randomly tagged plants.

### **3.2.9 Harvesting span (days)**

Number of days taken from first picking to last picking in each genotype was recorded as harvesting span.

## **B. Quantitative Traits**

### **3.3.1 Dry matter content (%)**

The pods from composite sample were taken randomly and washed then these were cut into small and thin pieces. 100 g sample from each replication was taken and dried to constant weight in an oven at  $60 \pm 2^\circ\text{C}$ . The per cent dry matter was estimated by following formula:"

$$\text{Dry matter (\%)} = \frac{\text{Final dry weight}}{\text{Initial fresh weight}} \times 100$$

### **3.3.2 Protein content (%)**

To determine total soluble protein by the Lowry's Method.

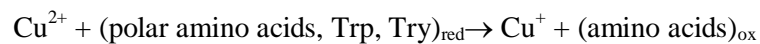
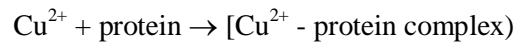
#### **Principle**

Lowry's method is most common colorimetric assays method for the estimation of proteins. This method is widely used to determine the protein content. This method utilizes

Folin phenol reagent and is much more sensitive than Biuret method. The principle is more or the less same as Biuret method. The protein concentration is determined with Folin-Ciocalteu phenol reagent, which couples redox reaction ( $\text{Cu}^+$  - formation, Biuret method) with a second redox reaction (color change).

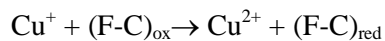
**Reaction:** Lowry assay relies on two reactions:

1. Formation of a complex between  $\text{Cu}^{2+}$  and protein amide (peptide) bonds in an alkaline solution causing a reduction of copper to  $\text{Cu}^+$ .



2.  $\text{Cu}^+$  and radical groups of tryptophan, tyrosine, and cysteine reduce a yellow phosphomolybdate-phosphotungstate complex (Folin-Ciocalteu reagent)

( $\text{Na}_2\text{MoO}_4 + \text{H}_3\text{PO}_4$ ) to a deep blue color



(F-C) = phospho-Mo-Tungstate acid

The method has clear cut advantage, as its very sensitive requiring only 10 to 200  $\mu\text{g}$  of proteins. A number of wavelengths possible for analysis i.e. 500-750 nm. It is a very good method for proteins containing chromophores (heme, flavins...) and requires inexpensive reagents. The disadvantage being gives non-linear concentration dependence curve. The protein amino acids variation can influence color development.

### Reagents

A: 2%  $\text{Na}_3\text{CO}_3$  in 0.1 N NaOH (91); B: 0.5%  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  in 1% sodium citrate, (92); C: 50 ml of reagent A + 1 ml of reagent; D: 1 part of phenol reagent+ 1 part of  $\text{H}_2\text{O}$ . Standard BSA 100'  $\mu\text{g}/\text{ml}$  (93).

**Glassware / equipment** -Test tubes; pipettes; test tube stand, spectrophotometer at 520 nm

### 3.3.3 Sugar content (%)

**Extraction of soluble sugars content from French bean (Dubios *et al* 1956).**

**Principle:** The soluble sugars get dissolved in 80% alcohol and residue remaining is starch and other components.

**Reagents:** Ethanol (80%), Ethanol (70%), saturated lead acetate solution, Sodium Oxalate crystals.

**Glassware/Equipment:** 30 ml cultural tubes (two); measuring cylinder (cap. 100 ml); volumetric flask (100 ml), Whatman filter paper No. 1, Magnetic stirrer with hot plate, table centrifuge, flash and evaporator.

**Procedure:****(A) Extraction procedure****a) Reagent****i) Ethanol (80%)****ii) Lead acetate (saturated)****iii) Sodium oxalate**

Take 500 mg dried samples and refluxed with ethanol (80%) in conical flask fitted with water condenser. The mixture was refluxed for two hours. Then supernatant was collected in conical flask and again refluxed the content with ethanol (70%). Then supernatants were pooled. Ethanol was removed from pooled extract at 50°C in a flask evaporator under vacuum. Put 1.0 ml of saturated lead acetate was added in the extract. The mixture was kept for overnight till all the proteins get precipitated in the extract. Add a pinch of sodium oxalate to remove the lead ions present in the extract and kept overnight. Thereafter, Whatman no. 1 filter paper was used for filtration of the extract. The clear extract thus obtained after filtration was made up to 100 ml volume using distilled water for sugar estimation.

**Estimation****a) Reagents****i) 5% phenol (w/v) redistilled****ii) Conc. Sulphuric acid (H<sub>2</sub>SO<sub>4</sub>).****b) Procedure**

To sugar extract (0.2 ml), distilled water (0.8 ml) and 5% phenol (1.0 ml) was added followed by the addition of conc. H<sub>2</sub>SO<sub>4</sub> (5.0 ml). The H<sub>2</sub>SO<sub>4</sub> was poured directly in the centre of the test tube to ensure proper mixing. After 10 min tubes were cooled to room temperature under running water. After 20 minutes, absorbance in spectrometer was read at 490 nm against blank reagent. The standard curve was prepared from concentration of total sugars by using glucose with concentration of 10-100 µg/ml.

**3.3.4 Fibre content (%)**

**Glassware/equipment:** Test tubes, pipettes, test tube stand, beaker and muffle furnace.

**Crude Fibre determination from French bean**

Sample with 1.25/H<sub>2</sub>SO<sub>4</sub> and 1.25/NaOH solution.

1.25% H<sub>2</sub>SO<sub>4</sub> Sol. [0.255 N]

1.25% NaOH Sol. [0.312 N]

**Procedure:**

1. Take 3g sample ( $W_1$ ) in conical flask and add 200 ml of  $H_2SO_4$  solution.
2. Boil it quickly for 30 minutes and add distilled water for maintaining constant volume upto 200 ml.
3. Extract was filtered through muslin cloth and give 5-6 washings with distilled water till washings are no longer acidic.
4. Transfer the residual material to beaker, add 200 ml NaOH solution and boil it for 30 minutes.
5. Filter the contents through muslin cloth and give 5-6 washings with distilled water till washings are no longer alkaline.
6. Add drops of ethanol to the extract and dry at  $110^\circ C$  (1 hour) in oven.
7. Cool the extract and weigh the sample ( $W_2$ ).
8. Keep the sample in muffle furnace at  $600^\circ C$  (4 hour).
9. Cool and weigh the extract ( $W_3$ ).

After this procedure fibre content determine using following formula

$$\text{Fibre content (\%)} = \frac{W_2 - W_3}{W_1} \times 100$$

**STATISTICAL ANALYSIS**

Data recorded for all the characters were subjected to analysis of variance by using randomized complete block design.

**Analysis of variance**

The table for analysis of variance (ANOVA) was set as explained by Gomez and Gomez (1984).

Source of variation	d. f.	Mean sum of squares	Expected mean squares	F value
Replication	(r-1)	$M_1$	$\sigma_e^2 + g\sigma_r^2$	$M_1/M_3$
Genotypes	(g- 1)	$M_2$	$\sigma_e^2 + r \sigma_g^2$	$M_2/M_3$
Error	(r-1) (g- 1)	$M_3$	$\sigma_e^2$	$M_3$
Total	(rg-1)			

Where,

r = Number of replications

g = Number of genotypes

$\sigma_r^2$  = The variance due to replications

$\sigma_g^2$  = The variance due to genotypes

$\sigma_e^2$  = The error variance

To compare the genotypic mean, standard error and critical difference (C.D.) of means for each character were calculated as below

$$\text{S.Ed} = \frac{\sqrt{2 \times \text{EMS}}}{r}$$

Where, EMS= error mean square

Each mean square of the genotype component was tested against corresponding error mean square (EMS) and calculated F value was compared with table value of F at P=0.05 and P=0.01 for respective components against error degree of freedom. In the case where F test was found to be significant, critical difference (C.D.) was calculated to find out the superiority of one genotype by following formula

$$\text{Critical difference (C.D.)} = \text{SE (difference)} \times t_{\text{edf}}$$

t = value against error degree of freedom at P= 0.05 and P=0.01 (t table)

Thus from this analysis different components of variance were calculated as:

$$\text{Genotypic variance } (\sigma_g^2) = \frac{M_2 - M_3}{r}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + \sigma_e^2$$

$$\text{Environmental variance } (\sigma_e^2) = \frac{\sigma_e^2}{r}$$

### **Estimation of Parameters of Genetic Variability**

The genotypic and phenotypic coefficients of variation, heritability in broad sense and expected genetic advance for various traits were calculated as per formula suggested by Burton and Devane (1953) and Johnson *et al* (1955) as under:

### **Genotypic and Phenotypic Coefficients of Variation**

$$\text{Genotypic coefficient of variation (GCV \%)} = \frac{\sigma_g}{X} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV \%)} = \frac{\sigma_p}{X} \times 100$$

Where

$\sigma_g$  = genotypic standard deviation

$\sigma_p$  = phenotypic standard deviation

$\bar{X}$  = Population mean of the trait under study

### Range of PCV and GCV

>20% = High

10-20% = Moderate

< 10% = Low

### Heritability ( $h^2$ bs)

Heritability (per cent) in broad sense was calculated by formula given by Allard (1960).

$$h^2 \text{ (bs)} = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

$\sigma_g^2$  = Genotypic Variance

$\sigma_p^2$  = Phenotypic variance

### Range of heritability

> 80 per cent = high

50- 80 per cent = Moderate

<50 per cent = Low

### Genetic Advance (GA)

Genetic Advance was calculated by formula used by Miller *et al* (1958). Thus,

$$GA = h^2.k.\sigma_p$$

Where,

$h^2$  = heritability

k= selection differential (at 5% selection intensity, k= 2.06)

$\sigma_p$  = Phenotypic variance

Genetic advance as % of mean will be

$$GA \text{ (\% of mean)} = \frac{GA}{\bar{X}} \times 100 \quad GA \text{ as (\% of mean)} = \frac{GA}{\bar{X}} \times 100$$

### Range of GA (% of mean)

>20% = High

10-20% = Moderate

<10% = Low

**Correlation coefficient**

Phenotypic and genotypic correlation coefficient was worked out by the formulae suggested by Al-Jibouri *et al* (1958).

**Phenotypic correlation co-efficient (r<sub>p</sub>)**

$$r_p = \sqrt{\frac{\sigma_{pxy}}{\sigma^2_{px} \times \sigma^2_{py}}}$$

Where,

$\sigma_{pxy}$ = Phenotypic covariance between two characters

$\sigma^2_{px}$ = Phenotypic variance of the x character

$\sigma^2_{py}$ = Phenotypic variance of the y character

**Genotypic correlation co-efficient (r<sub>g</sub>)**

$$r_g = \sqrt{\frac{\sigma_{gxy}}{\sigma^2_{gx} \times \sigma^2_{gy}}}$$

Where,

$\sigma_{gxy}$ = genotypic covariance between two characters

$\sigma^2_{gx}$ = genotypic variance of the x character

$\sigma^2_{gy}$ = genotypic variance of the y character

**Path Coefficient Analysis**

The path coefficient analysis of these characters which had shown significant correlations with yield was done by the method given by Dewey and Lu (1959). The direct and indirect effects were calculated 5by solving the following set of simultaneous equations.

$$P_{y1} + P_{y2} r_{13} + P_{y3} r_{13+} \dots\dots\dots P_{yn} r_{1n} = r_{y1}$$

$$P_{y1} + P_{y2} + P_{y3} r_{23+} \dots\dots\dots P_{yn} r_{2n} = r_{y2}$$

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$$P_{y1} r_{1n} + P_{y2} r_{2n} + P_{y3} r_{3n+} \dots\dots\dots P_{yn} = r_{y1}$$

Where,

$P_{y1} + P_{y2} + P_{y3} \dots\dots\dots P_{yn}$  are the direct effects of 1, 2, 3....., n variables on dependent variable 'y',  $r_{12}, r_{13}, r_{14} \dots\dots\dots, r_{(t-1)n}$  are the genotypic coefficient of correlation between various dependent variables,  $r_{y1}, r_{y2}, \dots\dots\dots, r_{yn}$  are the genotypic correlation coefficients of independent variables with dependent variable 'y' and  $P_{y1} r_{12}, P_{y3} r_{23}, \dots\dots\dots P_{yn} r_{2n}$  are the indirect effects.

The variation within the dependent variable which remained undetermined by including all variables was assumed to be due to variable (s) not included in the present investigation. The degrees of determination ( $P^2_{xy}$ ) of such variable(s) on dependent variable was calculated as follows:

$$P^2_{xy} = 1 - (P^2_{y1} + 2P_{y1}P_{y2}r_{12} + 2P_{y1}P_{y3}r_{13} \dots + P^2_{y2} + 2P_{y2}P_{y3}r_{23} + P^2_{y3} + 2P_{y3}P_{y4}r_{34} \dots + P^2_{yn})$$

Where,

$$\text{Residual effects } (R^2) = P^2_{yx}$$

## CHAPTER IV

### RESULTS AND DISCUSSION

The present investigation entitled “Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house” was undertaken on 29 genotypes of French bean including check ‘Kentucky Wonder’ to obtain information regarding the genetic variation, heritability, genetic advance as percentage of mean, correlation and path coefficient. The results of the mean performance of yield and yield attributing traits of 29 genotypes are presented as:

#### 4.1 Yield and yield parameters

##### 4.1.1 Days to 50% flowering

Earliness is an important character in vegetable crops. Early maturing varieties are generally preferred because of price advantage during early season. The plants which take less days for 50% flowering are considered to be early yielder. The significant variation was observed among all the genotypes for days to 50% flowering in both the years (Table 2). During 2016-17, the number of days taken to 50% flowering varied from 61.33 to 106.67 whereas, during 2017-18 it varied from 64.33 to 109.67. During 2016-17, genotype FBK-10 was early yielder among all the genotypes as it took least days (61.33 days) to 50% flowering and it was significantly superior to rest of the genotypes and the check Kentucky Wonder (76.33 days). The maximum number of days to 50% flowering was observed in genotypes FBK-3 (106.67 days) and Titra Mitra (105.33 days) and both these genotypes were statistically at par with each other with mean value of 76.98 days for all the genotypes. It was observed that genotypes FBB Var-3 (65.67 days), AVT Var-1 (68.67 days) and AVT Var-2 (69.00 days) were statistically at par with each other (Fig 4.1) and were also observed to be early in 50% flowering. During 2017-18, significant differences were observed among all genotypes for days to 50% flowering (Table 2). The genotype ‘AVT Var-2’ was early yielder among all genotypes and took 64.33 days to reach 50% flowering which was statistically at par with FBK-10 (64.33 days) and significantly different from all the other genotypes (Fig 4.2) and check ‘Kentucky Wonder’. It was also observed that genotypes FBB Var-4 (69.67 days) and Stringless Blue Lake (70.67 days) were also early yielders and statistically at par with each other. The genotypes Titra Mitra (105.67 days) and FBK-3 (109.67 days) were consistently late to reach 50% flowering but were observed to be significantly different from each other. The pooled data of both years showed that FBK-10 (62.83 days) was earliest to reach 50% flowering and was significantly better than check ‘Kentucky wonder’ and rest of the genotypes (Table 2).

The pooled analysis of both years, it was also observed that genotypes FBB Var-3 (66.33 days), AVT Var-2 (66.67 days) and AVT Var-1 (68.00 days)

**Table 2: Mean values of genotypes for days to 50% flowering and days to first harvest**

Sr no	Genotypes	Days to 50% flowering			Days to first harvest		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	74.67	78.67	76.67	119.67	123.67	121.67
2	Lakshmi	78.67	76.00	77.33	105.33	108.33	106.83
3	Kentucky Blue	78.00	82.67	80.33	117.67	121.33	119.50
4	Stringless Blue Lake	71.67	70.67	70.17	114.33	117.67	116.00
5	Titra Mitra	105.33	105.67	105.50	132.33	130.67	131.50
6	AVT Var-1	68.67	67.33	68.00	116.00	116.67	116.33
7	AVT Var-2	69.00	64.33	66.67	112.33	111.67	112.00
8	AVT Var-3	71.33	76.67	74.00	114.67	115.00	114.83
9	FBB Var-1	76.67	77.67	77.17	115.00	116.67	115.83
10	FBB Var-2	76.00	76.67	76.83	108.00	110.00	109.00
11	FBB Var-3	65.67	67.00	66.33	114.33	116.33	115.33
12	FBB Var-4	71.00	69.67	70.33	109.67	108.00	108.83
13	FBK-1	75.67	77.33	76.50	105.67	113.00	109.33
14	FBK-3	106.67	109.67	108.17	134.67	139.00	136.83
15	FBK-4	74.33	75.33	74.83	108.67	111.00	109.83
16	FBK-5	76.33	77.67	77.00	115.00	113.67	114.33
17	FBK-6	79.00	76.00	77.50	122.00	118.33	120.17
18	FBK-7	76.67	79.00	77.83	121.67	124.33	123.00
19	FBK-8	76.33	79.67	78.00	117.67	121.67	119.67
20	FBK-9	75.00	77.67	76.33	113.33	115.67	114.50
21	FBK-10	61.33	64.33	62.83	104.00	107.00	105.50
22	FBK-11	70.67	72.67	71.67	116.00	118.67	117.33
23	FBK-12	85.67	87.67	86.67	127.33	129.67	128.50
24	FBK-13	75.00	73.00	74.00	111.33	113.67	112.50
25	FBK-14	90.33	87.67	89.00	129.33	128.00	128.67
26	FBK-15	76.33	72.67	74.50	114.33	110.33	112.33
27	FBK-16	73.67	78.33	76.00	116.33	120.00	118.17
28	FBK-17	76.33	80.00	78.17	115.00	120.33	117.67
29	Kentucky Wonder (C)	76.33	80.00	78.17	121.00	123.00	122.00
<b>Grand Mean</b>		76.98	78.02	77.50	116.30	118.16	117.17
<b>CV</b>		1.70	1.54	2.42	1.66	1.95	1.83
<b>CD</b>		2.14	2.02	2.14	3.15	2.60	2.45
<b>Range</b>		61.33-106.67	64.33-109.67	62.83-108.17	104.00-134.67	107.00-139.00	105.50-136.83

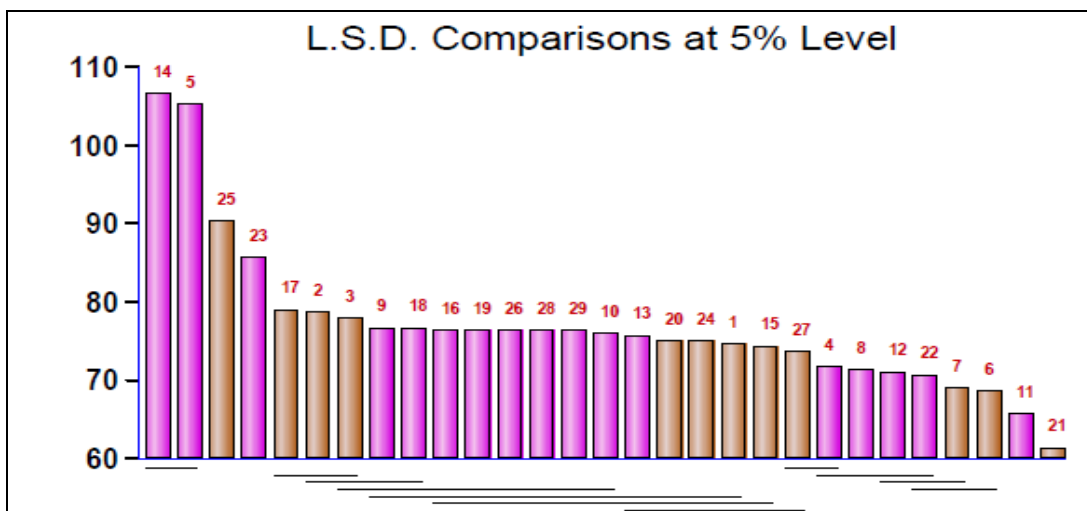


Fig. 4.1: LSD comparison of genotypes for days to 50% flowering (2016-17)

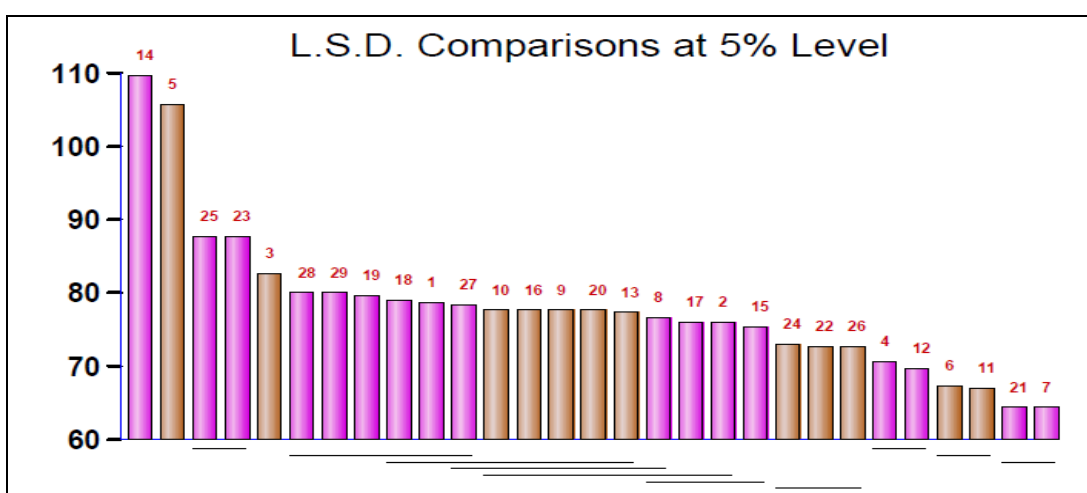


Fig. 4.2: LSD comparison of genotypes for days to 50% flowering (2017-18)

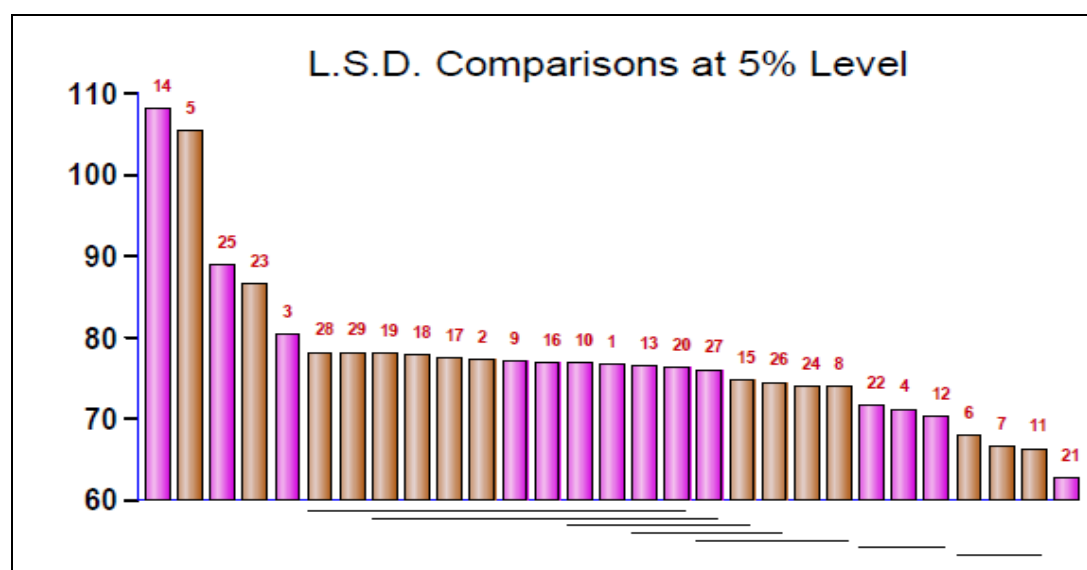


Fig. 4.3: LSD comparison of genotypes for days to 50% flowering (Pooled)

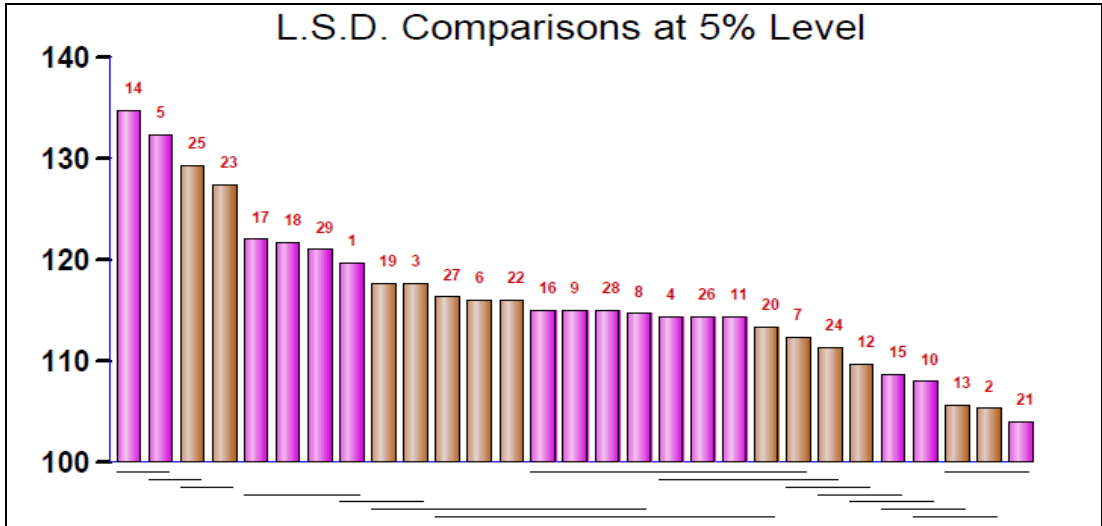


Fig. 4.4: LSD comparison of genotypes for days to first harvest (2016-17)

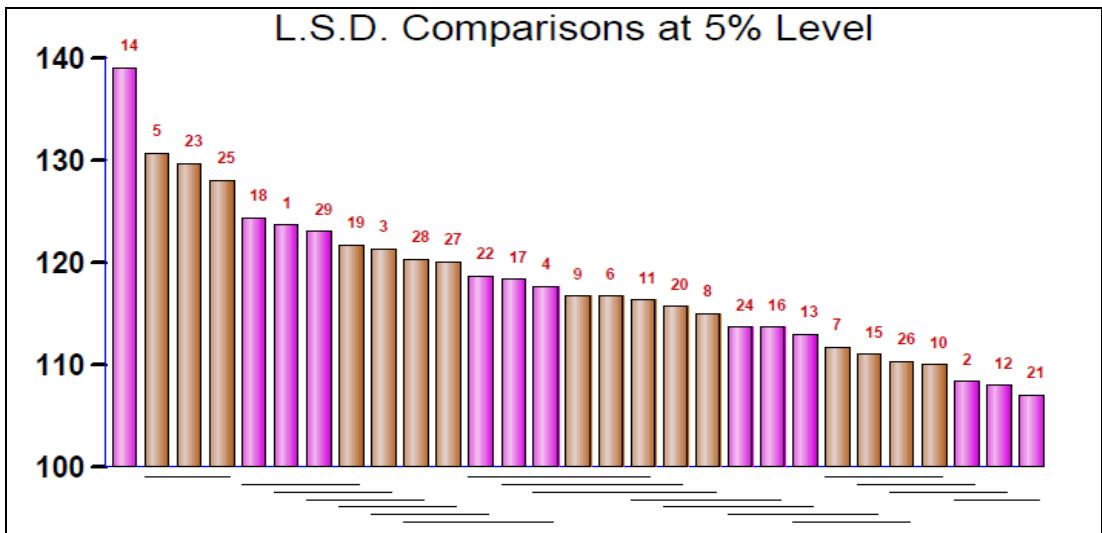


Fig. 4.5: LSD comparison of genotypes for days to first harvest (2017-18)

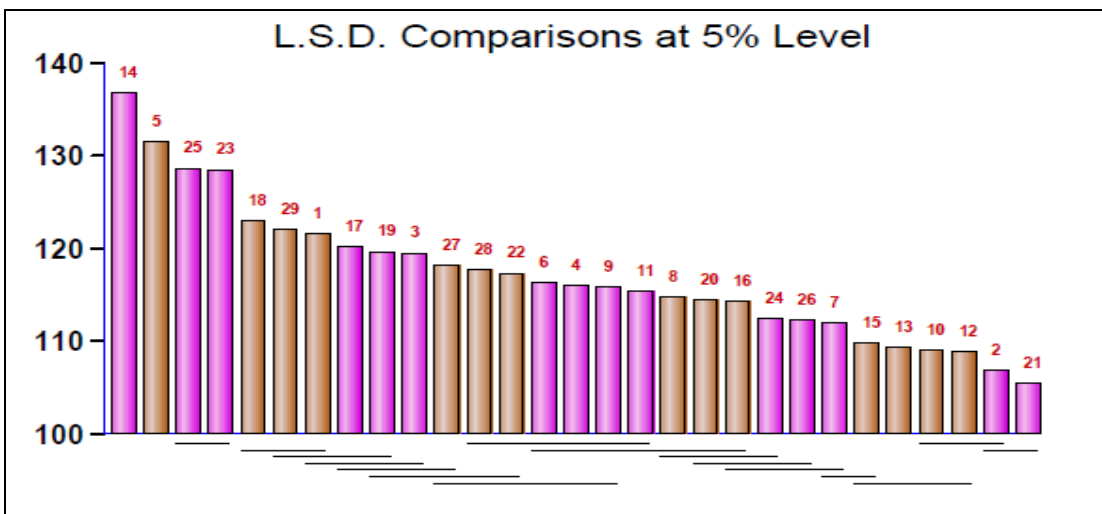


Fig. 4.6: LSD comparison of genotypes for days to first harvest (Pooled)

were statistically at par with each other and also observed to be early in 50% flowering (Fig 4.3). However, genotypes FBK-3 (108.17 days) and Titra Mitra (105.50 days) took maximum days to reach 50% flowering. Similar results were reported by Kumar *et al* (2014) and Prakash *et al* (2015) for flowering in French bean.

#### **4.1.2 Days to first harvest**

The perusal of data showed that the significant differences were observed among all the genotypes for days to first pod harvest. The number of days to first picking varied from 104.00-134.67 during 2016-17, 107.00-139.00 during 2017-18 and 105.50 to 136.83 during pooled mean analysis of both years. During 2016-17, genotype FBK-10 (104.00 days) took minimum days to first harvest which clearly revealed the days to 50% flowering effect the time to first harvest and it was closely followed by Lakshmi (105.33 days) and FBK-1 (105.67 days) which were statistically at par with each other but significantly higher than rest of genotypes and the check 'Kentucky Wonder' (Fig 4.4). It was also observed that genotypes FBK-3 (134.67 days), Titra-Mitra (132.33 days) took maximum days to first harvest and were statistically at par with each other. During 2017-18, genotype FBK-10 was earliest to first harvest (107.00 days) and was observed to be statistically at par with FBB Var-4 (108.00 days) and Lakshmi (108.33 days). However, FBK-3 (139.00 days) was most late genotype for harvesting (Table 2).

The pooled data of both years for first harvest showed that genotype FBK-10 was earliest to first harvest (105.50 days) followed by Lakshmi (106.83 days) which were statistically at par with each other and observed to be significantly better than the check 'Kentucky Wonder' (Table 2). It was also observed that the genotypes FBB Var-4 (108.83 days) and FBB Var-2 (109.00 days) were statistically at par with each other and were earlier to first harvest than check with mean value of 122.00 days (Fig 4.6). It was observed that genotype FBK-3 (136.83 days) took maximum days to first harvesting. Similar results were corroborated by Kumar *et al* (2014) and Singh *et al* (2017).

#### **4.1.3 Number of pods per plant**

Number of pods per plant is an important yield component. The evaluated data showed significant variation among all genotypes for number of pods per plant in both years (Table 3). During 2016-17, number of pods per plant varied from 67.67 to 162.67 whereas, during 2017-18 number of pods per plant varied from 71.67 to 155.33. During 2016-17, maximum pods per plant were obtained from Lakshmi (162.67) followed by Star-1 (159.00) and both these genotypes were statistically at par with each other but significantly higher than other genotypes and check 'Kentucky Wonder'. The genotype FBK-13 had minimum pods per plant (67.67) and was observed to be significantly different from all genotypes (Fig 4.7).

During 2017-18, maximum pods per plant were recorded in genotype Star-1 (155.33) followed by FBK-4 (148.67), Lakshmi (146.33) and FBK-16 (146.33) which were statistically at par with each other and significantly higher than rest of genotypes and check 'Kentucky Wonder'. The genotype FBK-17 (71.67) recorded minimum pods per plant followed by Titra Mitra (72.00) and FBK-13 (75.00) which were statistically at par with each other (Fig 4.8).

The pooled data of both years showed that number of pods per plant varied from 71.33 to 157.17. The maximum number of pods was observed in genotype Star-1 (157.17) followed by Lakshmi (154.50), FBK-4 (146.50) and FBK-16 (144.17) which were statistically at par with each other and significantly higher than rest of genotypes and check (Fig 4.9). The genotype FBK-13 recorded minimum pods per plant (71.33) which was statistically at par with genotypes FBK-17 (75.33) and Titra Mitra (77.83). Similar results were corroborated by Kumar *et al* (2014) and Mehra *et al* (2016).

#### **4.1.4 Pod weight (g)**

Pod weight is another yield component and needs due consideration while making selection for yield. The findings of present investigation showed significant variation for pod weight among all the genotypes. During 2016-17, pod weight varied from 4.60 g to 7.31 g, however, it varied from 4.36 g to 7.81 g during 2017-18. During 2016-17, genotype AVT Var-3 recorded maximum pod weight (7.31 g) followed by FBB Var-1 (7.27 g), Kentucky Blue (7.22 g) and AVT Var-2 (7.05 g) which were statistically at par with each other but significantly higher than rest of genotypes and check 'Kentucky Wonder' (Fig 4.10). The minimum pod weight was recorded in genotype FBK-8 (4.60 g) followed by FBK-15 (4.85 g) and Titra Mitra (5.02 g) which were statistically at par with each other. During 2017-18, maximum pod weight was recorded in genotype FBB Var-1 (7.81 g) followed by FBK-7 (7.54 g), FBB Var-2 (7.49 g), Kentucky Blue (7.48 g) and AVT Var-2 (7.25 g) which were statistically at par with each other but significantly higher than rest of genotypes including check (Fig 4.11). Pod weight was recorded minimum in FBK-8 (4.36 g) followed by FBK-15 (4.43 g) and FBK-5 (4.80 g) which were statistically at par with each other.

The pooled data of both years showed that the variation for this character is quite high which might be responsible for the wide range in yield potential of different genotypes. The maximum pod weight was observed in genotype FBB Var-1 (7.54 g) followed by Kentucky Blue (7.35 g), AVT Var-2 (7.15 g) and FBB Var-2 (7.12 g) which were statistically at par with each other but higher than rest of the genotypes and check 'Kentucky Wonder' (Fig 4.12). It was observed that genotype FBK-8 had minimum pod weight of 4.48 g followed by FBK-15 (4.64 g) and both genotypes were statistically at par with each other. Similar results were observed by Kumar *et al* (2014) in French bean.

**Table 3: Mean values of genotypes for number of pods per plant and pod weight (g)**

Sr no	Genotypes	Number of pods per plant			Pod weight (g)		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	159.00	155.33	157.17	6.04	6.29	6.17
2	Lakshmi	162.67	146.33	154.50	6.22	6.68	6.45
3	Kentucky Blue	121.67	117.00	119.33	7.22	7.48	7.35
4	Stringless Blue Lake	108.33	116.00	112.17	6.65	6.14	6.39
5	Titra Mitra	83.67	72.00	77.83	5.02	5.45	5.23
6	AVT Var-1	131.00	123.33	127.17	5.20	5.77	5.48
7	AVT Var-2	96.33	91.00	93.67	7.05	7.25	7.15
8	AVT Var-3	125.33	137.33	131.33	7.31	6.90	7.11
9	FBB Var-1	110.33	106.67	108.50	7.27	7.81	7.54
10	FBB Var-2	100.67	92.00	96.33	6.75	7.49	7.12
11	FBB Var-3	113.67	137.33	125.50	6.66	5.78	6.22
12	FBB Var-4	106.67	96.33	101.50	6.59	7.16	6.87
13	FBK-1	124.33	135.33	129.83	6.87	6.46	6.66
14	FBK-3	110.67	123.00	116.83	5.96	4.98	5.47
15	FBK-4	144.33	148.67	146.50	6.34	6.38	6.36
16	FBK-5	97.33	111.67	104.50	5.40	4.80	5.10
17	FBK-6	79.67	92.00	85.83	5.97	5.05	5.51
18	FBK-7	110.67	100.33	105.50	6.67	7.54	7.11
19	FBK-8	105.00	128.67	116.83	4.60	4.36	4.48
20	FBK-9	115.00	116.33	115.67	6.02	6.15	6.09
21	FBK-10	125.00	104.00	114.50	5.49	6.58	6.03
22	FBK-11	136.67	140.67	138.67	5.61	5.56	5.85
23	FBK-12	82.33	86.67	84.50	6.93	7.13	7.03
24	FBK-13	67.67	75.00	71.33	5.26	5.25	5.25
25	FBK-14	122.33	132.67	127.50	5.37	5.20	5.29
26	FBK-15	89.67	102.00	95.83	4.85	4.43	4.64
27	FBK-16	142.00	146.33	144.17	5.22	5.27	5.24
28	FBK-17	79.00	71.67	75.33	5.78	6.79	6.28
29	Kentucky wonder (C)	122.33	125.00	123.67	6.84	6.50	6.67
<b>Grand Mean</b>		112.87	114.85	113.86	6.11	6.16	6.13
<b>CV</b>		10.21	11.25	10.03	10.34	8.09	9.50
<b>CD</b>		18.84	16.19	13.04	1.03	0.75	0.67
<b>Range</b>		67.67-162.67	71.67-155.33	71.33-157.17	4.60-7.31	4.36-7.81	4.48-7.54

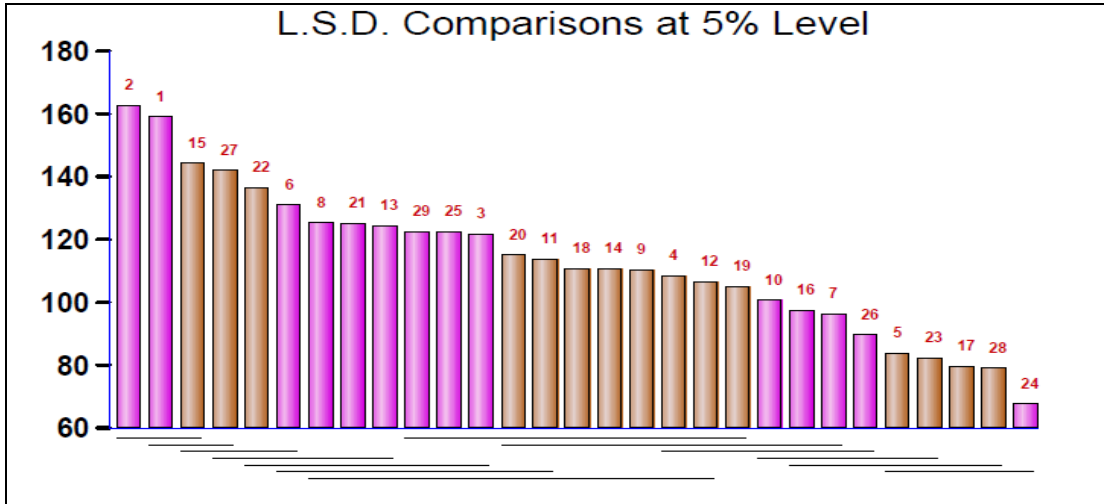


Fig. 4.7: LSD comparison of genotypes for number of pods per plant (2016-17)

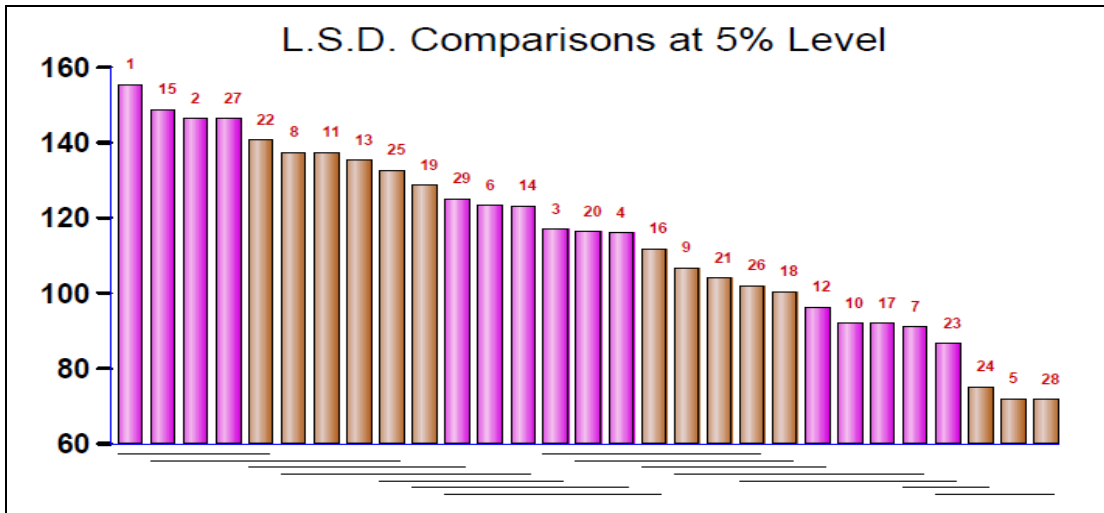


Fig. 4.8: LSD comparison of genotypes for number of pods per plant (2017-18)

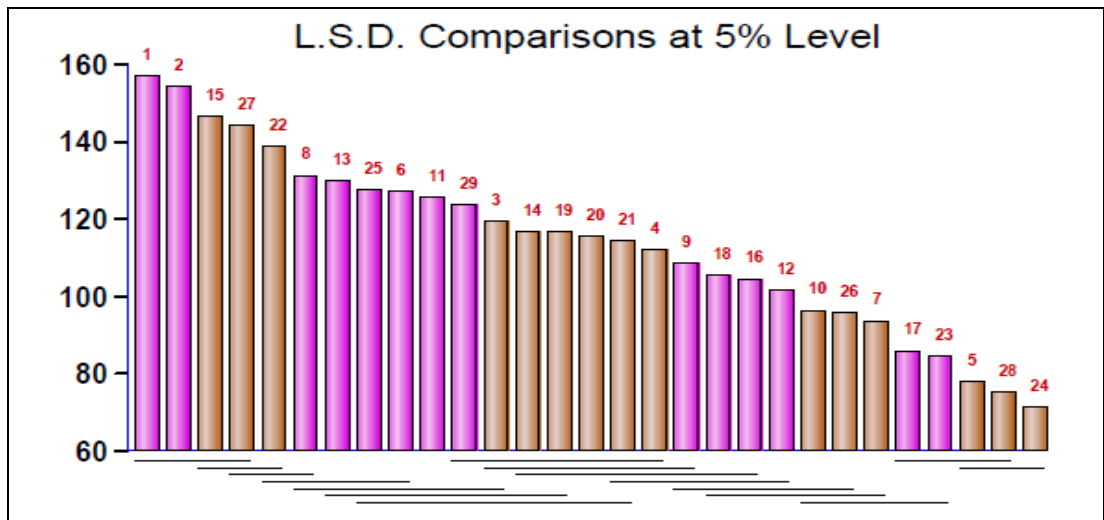


Fig. 4.9: LSD comparison of genotypes for number of pods per plant (Pooled)

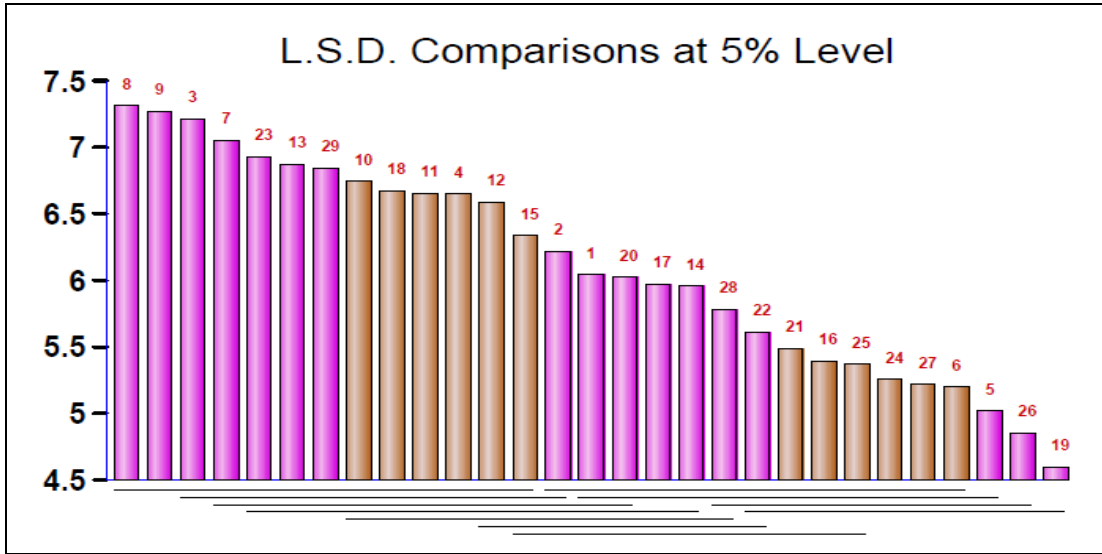


Fig. 4.10: LSD comparison of genotypes for pod weight (2016-17)

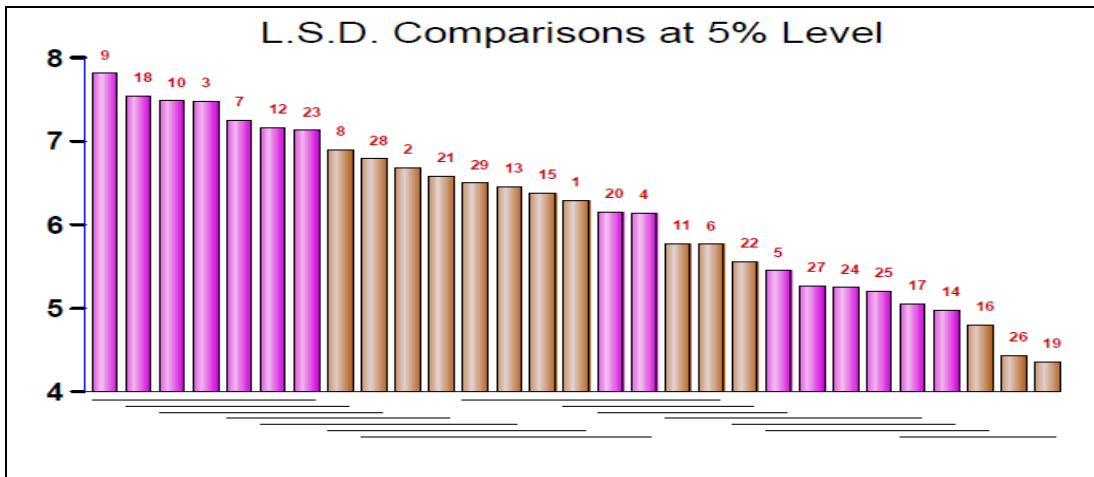


Fig. 4.11: LSD comparison of genotypes pod weight (2017-18)

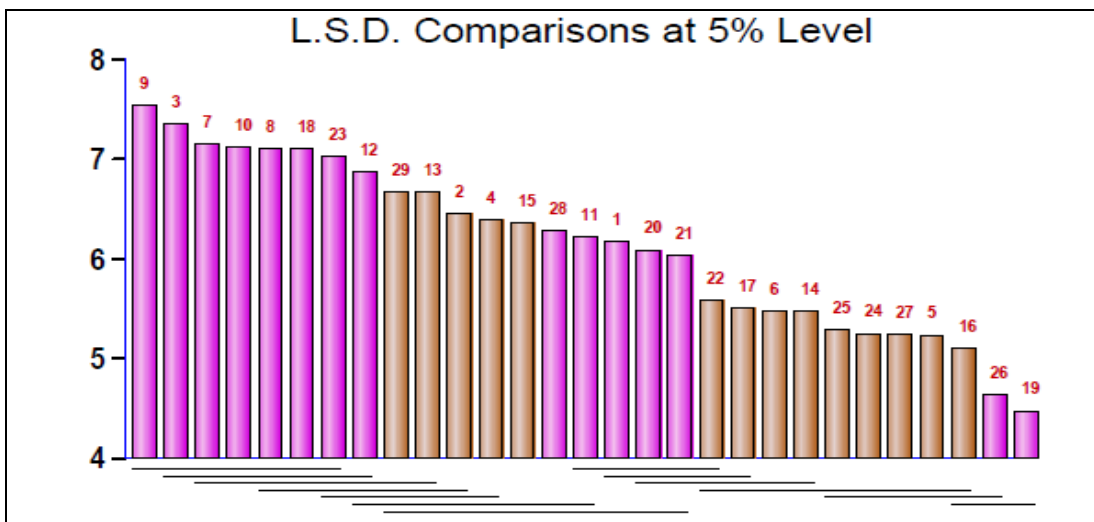


Fig. 4.12: LSD comparison of genotypes for pod weight (Pooled)

#### **4.1.5 Pod length (cm)**

Pod length is also one of the important character affecting yield. The significant variation was observed for pod length in all the genotypes during both years. During 2016-17, pod length ranged from 10.16 cm to 15.82 cm whereas, during 2017-18, pod length varied from 8.76 cm to 14.45 cm among all genotypes (Table 5). The data recorded for pod length during 2016-17 revealed that the maximum pod length was observed in Kentucky Blue (15.82 cm) followed by FBB Var-2 (15.02 cm), AVT Var-2 (14.94 cm) and FBB Var-4 (14.73 cm) which were statistically at par with each other but significantly higher than rest of the genotypes and check (Fig 4.13). Minimum pod length was recorded in genotype FBK-14 (10.16 cm) closely followed by FBK-8 (10.46 cm) and FBK-15 (10.76 cm) which were statistically at par with each other. During 2017-18, maximum pod length was observed in Kentucky Blue (14.45 cm) followed by AVT Var-2 (14.15 cm), FBB Var-4 (14.14 cm) and FBB Var-2 (14.08 cm) which were statistically at par with each other and significantly higher than rest of genotypes and check 'Kentucky Wonder' (Fig 4.13). The pod length was minimum in genotype FBK-14 (8.76 cm) closely followed by FBK-8 (9.19 cm) which were statistically at par with each other.

In the pooled data of both years, ample variation existed for this character which showed a great scope of the improvement of this character. The maximum pod length was recorded in Kentucky Blue (15.13 cm) closely followed by AVT Var-2 (14.55 cm), FBB Var-4 (14.42 cm) and FBB Var-2 (14.55 cm) which were statistically at par with each other and significantly higher than rest of the genotypes including check (Fig 4.15). The minimum pod length was recorded in genotype FBK-14 (9.46 cm) closely followed by FBK-8 (9.82 cm) and FBK-5 (10.46 cm) which were statistically at par with each other. The results are supported by the studies of Pandey *et al* (2011), Parkash *et al* (2015) and Kumar *et al* (2014).

#### **4.1.6 Pod width (cm)**

The evaluated data for pod width showed significant variation among all genotypes during both years (Table 4). During 2016-17, pod width ranged from 0.66 cm to 1.00 cm in all genotypes whereas during 2017-18, pod width varied from 0.67 cm to 0.99 cm. During 2016-17, maximum pod width was observed in genotypes FBK-5 (1.00 cm) and FBK-8 (1.00 cm) followed by FBK-15 (0.98 cm) and FBK-17 (0.96 cm) which were statistically at par with each other and significantly higher than rest of the genotypes and check 'Kentucky Wonder' which recorded pod width of 0.87 cm (Fig 4.16). The minimum pod width was recorded in Kentucky Blue (0.66 cm) followed by AVT Var-1 (0.74 cm), FBB Var-1 (0.74 cm) and AVT Var-2 (0.74 cm) which were statistically at par with each other (Fig 4.16). During 2017-18, highest pod width was

**Table 4: Mean values of genotypes for pod length (cm) and pod width (cm)**

Sr no	Genotypes	Pod length (cm)			Pod width (cm)		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	12.19	11.48	11.84	0.86	0.89	0.87
2	Lakshmi	13.02	12.07	12.55	0.88	0.86	0.87
3	Kentucky Blue	15.82	14.45	15.14	0.66	0.67	0.67
4	Stringless Blue Lake	12.16	11.71	11.94	0.79	0.76	0.78
5	Titra Mitra	11.25	10.26	10.75	0.85	0.86	0.85
6	AVT Var-1	13.94	12.93	13.43	0.74	0.83	0.79
7	AVT Var-2	14.94	14.15	14.55	0.75	0.78	0.76
8	AVT Var-3	13.58	12.30	12.94	0.83	0.83	0.83
9	FBB Var-1	14.28	13.74	14.01	0.74	0.82	0.78
10	FBB Var-2	15.02	14.08	14.55	0.81	0.76	0.78
11	FBB Var-3	13.95	12.88	13.41	0.83	0.84	0.83
12	FBB Var-4	14.73	14.11	14.42	0.83	0.82	0.83
13	FBK-1	12.69	12.33	12.51	0.88	0.90	0.89
14	FBK-3	11.07	10.38	10.72	0.90	0.87	0.89
15	FBK-4	12.05	11.97	12.01	0.92	0.95	0.94
16	FBK-5	11.46	9.45	10.46	1.00	0.90	0.95
17	FBK-6	11.61	9.83	10.72	0.92	0.90	0.91
18	FBK-7	13.04	12.32	12.68	0.85	0.84	0.85
19	FBK-8	10.46	9.19	9.82	1.00	0.94	0.97
20	FBK-9	12.79	12.98	12.88	0.84	0.92	0.88
21	FBK-10	11.50	11.56	11.53	0.85	0.83	0.84
22	FBK-11	11.19	10.60	10.89	0.84	0.86	0.85
23	FBK-12	11.95	11.47	11.71	0.88	0.83	0.86
24	FBK-13	11.48	11.03	11.25	0.89	1.00	0.95
25	FBK-14	10.16	8.76	9.46	0.95	0.91	0.93
26	FBK-15	10.76	9.94	10.35	0.98	0.91	0.95
27	FBK-16	11.47	9.99	10.73	0.90	0.93	0.92
28	FBK-17	12.46	11.98	12.22	0.96	1.01	0.99
29	Kentucky wonder (C)	13.15	12.55	12.85	0.87	0.82	0.84
<b>Grand Mean</b>		12.56	11.74	12.15	0.86	0.86	0.86
<b>CV</b>		5.38	5.09	5.23	9.66	8.24	9.22
<b>CD</b>		1.10	0.98	0.73	0.14	0.12	0.09
<b>Range</b>		10.16-15.2	8.76-14.45	9.46-15.13	0.66-1.00	0.67-1.01	0.67-0.99

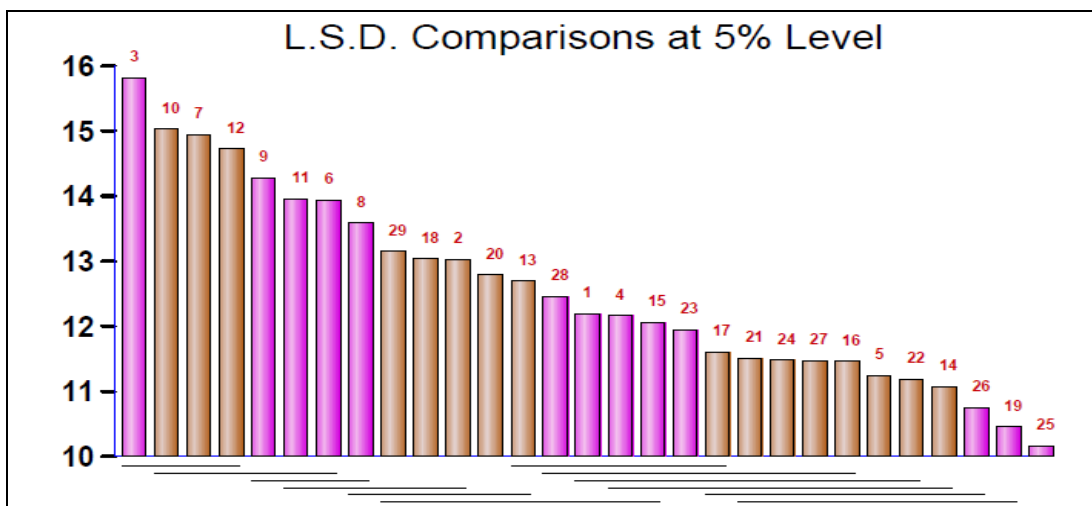


Fig. 4.13: LSD comparison of genotypes for pod length (2016-17)

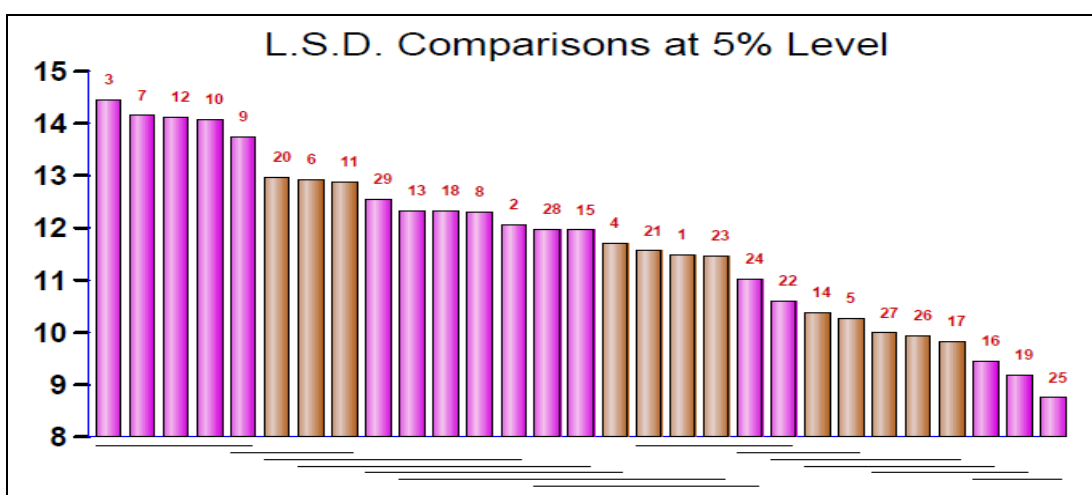


Fig. 4.14: LSD comparison of genotypes for pod length (2017-18)

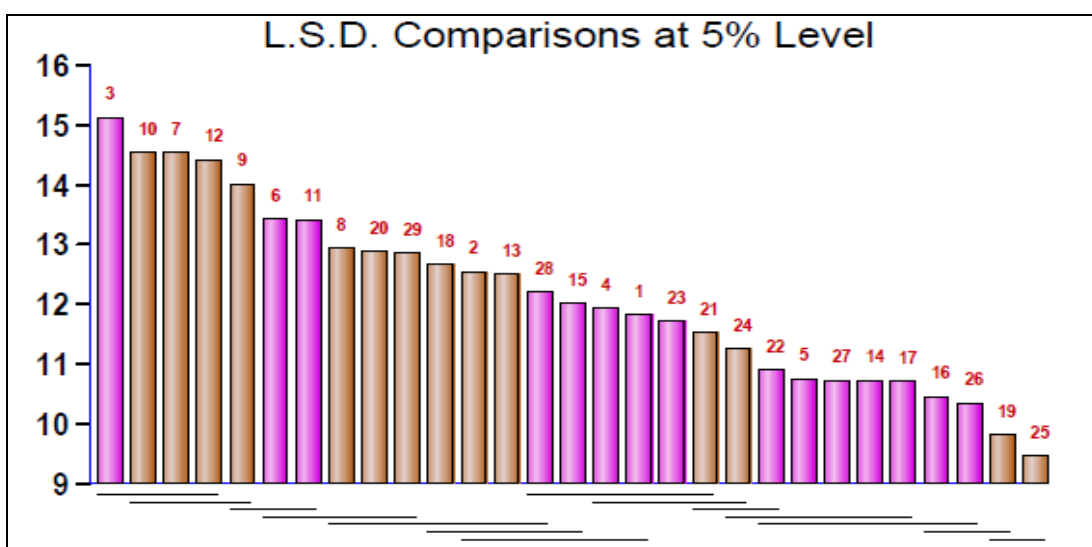


Fig. 4.15: LSD comparison of genotypes for pod length (Pooled)

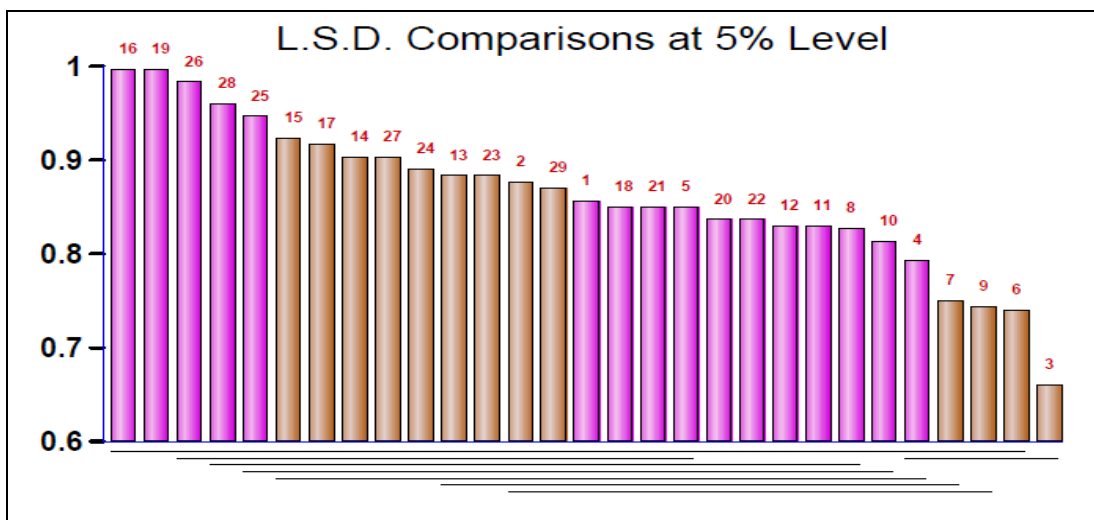


Fig. 4.16: LSD comparison of genotypes for pod width (2016-17)

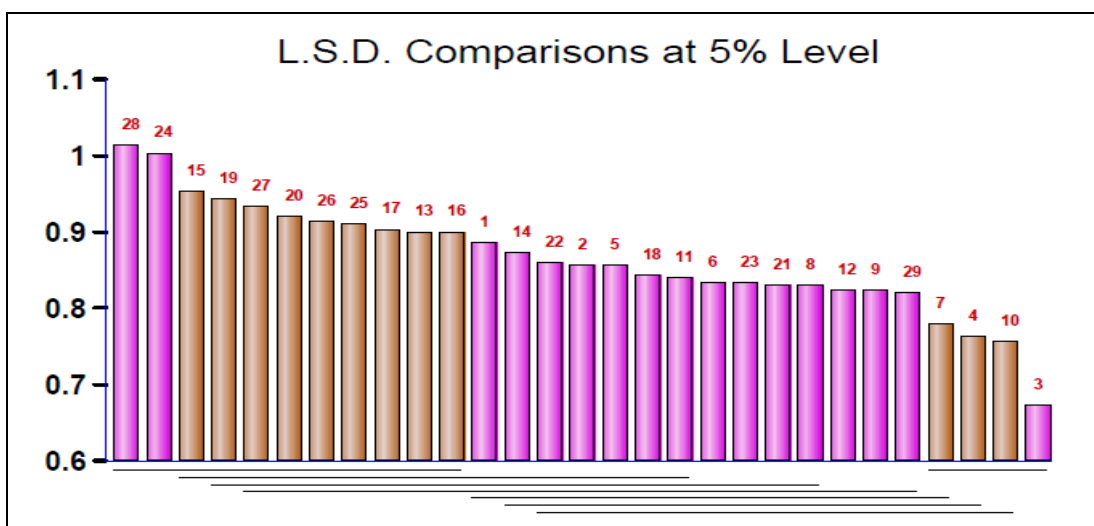


Fig. 4.17: LSD comparison of genotypes for pod width (2017-18)

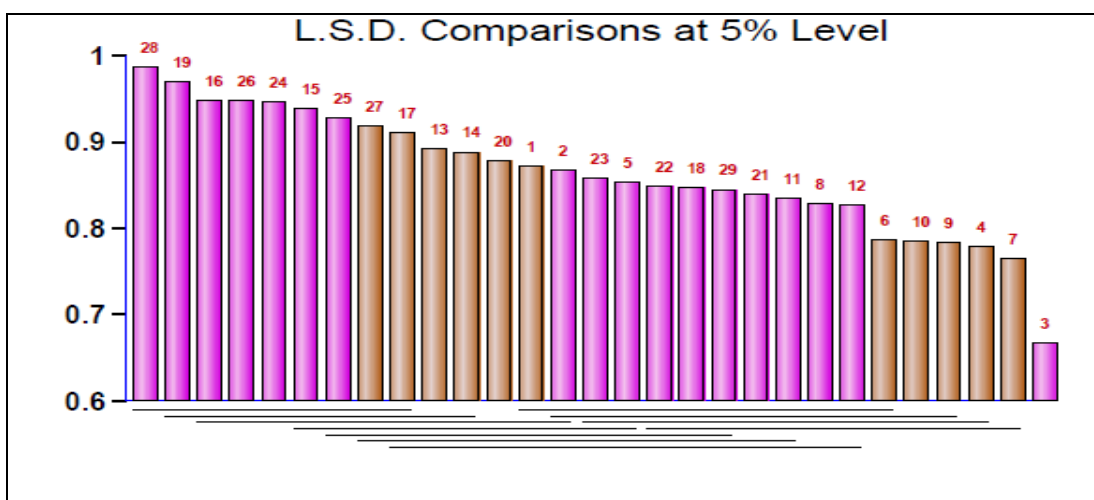


Fig. 4.18: LSD comparison of genotypes for pod width (Pooled)

recorded in FBK-17 (1.01 cm) followed by genotype FBK-13 (1.00 cm) which were statistically at par with each other and significantly higher than all genotypes including check 'Kentucky Wonder' (Fig 4.17). The lowest value of pod width was recorded in Kentucky Blue (0.67 cm) which was significantly different from all other genotypes.

The pooled data of both years revealed that highest pod width was recorded in FBK-17 (0.99 cm) followed by FBK-8 (0.97 cm), FBK-5 and FBK-15 (0.95 cm) which were statistically at par with each other and significantly higher than rest of genotypes including check which showed 0.67 cm pod width (Fig 4.18). The lowest value of pod width was observed for genotype Kentucky Blue (0.67 cm) which was significantly different from all other genotypes. The results are in accordance with studies of Kumar *et al* (2014) and Parkash *et al* (2015).

#### **4.1.7 Green pod yield per plant (g)**

The perusal of data showed significant variation was observed among genotypes for green pod yield per plant. During 2016-17, green pod yield per plant ranged from 343.33 g to 981.67 g whereas during 2017-18, yield varied from 366.67 g to 1003.00 g (Table 5). The highest pod yield per plant was observed in genotype Lakshmi (981.67 g) followed by genotype Star-1 (947.67 g) which were statistically at par with each other and significantly higher than rest of genotypes including check (Fig 4.19). The lowest pod yield per plant was observed in genotype FBK-13 (343.33 g) followed by Titra Mitra (388.00 g) and FBK-15 (414.00 g) which were statistically at par with each other. During 2017-18, maximum green pod yield was observed in genotype Lakshmi (1003.00 g) statistically at par with Star-1 (963.33 g) which were significantly higher than rest of genotypes including check 'Kentucky Wonder' (Fig 4.20). The lowest green pod yield was recorded in genotype Titra Mitra (366.67 g) followed by FBK-13 (377.33 g) which were statistically at par with each other.

The pooled data analysis of both years revealed that green pod yield per plant varied from 360.33 g to 992.33 g. The maximum green pod yield was recorded for genotype Lakshmi (922.33 g) followed by Star-1 (955.50 g) which were statistically at par with each other and significantly higher than all other genotypes including check (Fig 4.21). However, lowest pod yield per plant was observed in FBK-13 (360.33 g) followed by Titra Mitra (377.33 g) which were statistically at par with each other. Similar results for pod yield per plant were reported by Kumar *et al* (2014) and Prakash *et al* (2011) in pole type French bean.

#### **4.1.8 Number of pickings**

The perusal of data showed significant variation for number of pickings over both the years. The number of pickings varied from 5.00 to 10.00 during 2016-17, whereas from 4.33 to 10.00 during 2017-18 and 4.67 to 10.00 during pooled means of both years (Table 5). During 2016-17, maximum pickings were observed in Lakshmi (10.00) which was significantly higher than all other genotypes including check (7.67) (Fig 4.22). However,

**Table 5: Mean values of genotypes for green pod yield per plant (g) and number of pickings**

Sr no	Genotypes	Green pod yield per plant (g)			Number of pickings		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	947.67	963.33	955.50	9.00	9.00	9.00
2	Lakshmi	981.67	1003.00	992.33	10.00	10.00	10.00
3	Kentucky Blue	849.33	863.00	856.17	8.00	8.00	8.00
4	Stringless Blue Lake	687.33	682.67	685.00	7.00	7.00	7.00
5	Titra Mitra	388.00	366.67	377.33	5.00	4.33	4.67
6	AVT Var-1	667.00	684.00	675.50	7.00	7.00	7.00
7	AVT Var-2	655.33	645.33	650.33	6.00	6.00	6.00
8	AVT Var-3	893.33	923.67	908.50	9.00	9.00	9.00
9	FBB Var-1	775.00	803.67	789.33	7.00	8.00	7.50
10	FBB Var-2	648.33	669.33	658.83	6.00	6.00	6.00
11	FBB Var-3	728.67	744.33	736.50	7.00	7.00	7.00
12	FBB Var-4	658.00	686.00	672.00	7.00	7.33	7.17
13	FBK-1	826.67	858.67	842.67	8.33	8.67	8.50
14	FBK-3	633.00	608.33	620.67	6.00	6.00	6.00
15	FBK-4	896.67	925.67	911.17	9.00	9.00	9.00
16	FBK-5	475.33	498.67	487.00	5.00	5.67	5.33
17	FBK-6	456.67	445.67	451.17	6.00	6.00	6.00
18	FBK-7	704.00	735.33	719.67	8.00	8.00	8.00
19	FBK-8	460.00	495.33	477.67	5.33	5.00	5.17
20	FBK-9	654.00	673.67	663.83	6.00	6.00	6.00
21	FBK-10	651.33	664.67	658.00	7.00	7.00	7.00
22	FBK-11	740.67	765.33	753.00	7.00	7.00	7.00
23	FBK-12	545.00	561.67	553.33	6.00	6.33	6.17
24	FBK-13	343.33	377.33	360.33	5.00	5.00	5.00
25	FBK-14	634.33	665.67	650.00	6.00	6.00	6.00
26	FBK-15	414.00	439.33	426.67	5.00	5.00	5.00
27	FBK-16	721.67	744.33	733.00	7.00	7.00	7.00
28	FBK-17	444.67	466.33	455.50	5.00	5.00	5.00
29	Kentucky wonder (C)	783.00	803.67	793.33	7.67	8.00	7.83
<b>Grand Mean</b>		664.28	681.54	672.91	6.80	6.87	6.84
<b>CV</b>		4.33	5.08	5.01	2.66	3.46	3.60
<b>CD</b>		47.04	40.25	29.14	0.30	0.39	0.29
<b>Range</b>		343.33-981.67	366.67-1003.00	360.33-992.33	5.00-10.00	4.33-10.00	4.67-10.00

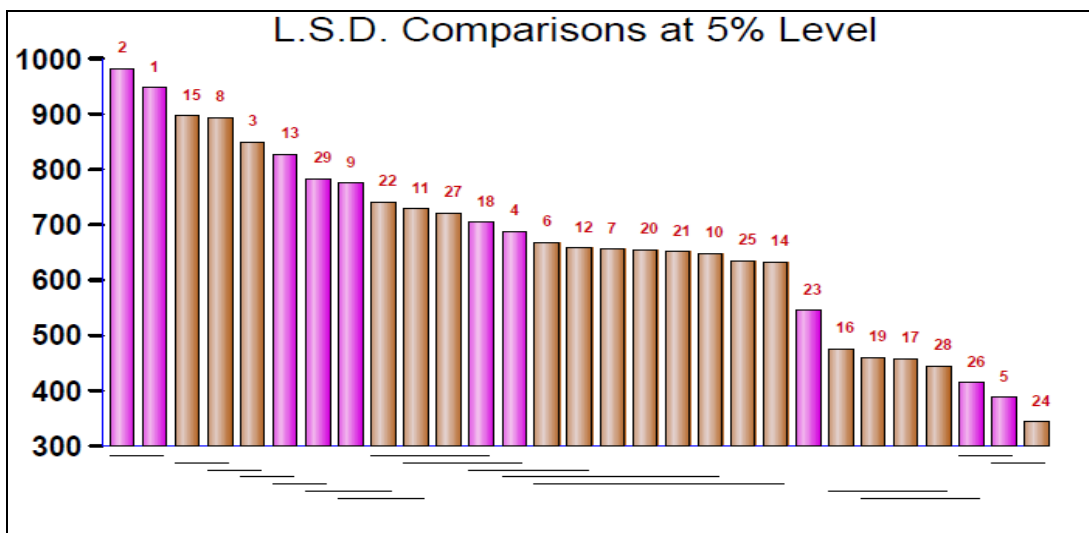


Fig. 4.19: LSD comparison of genotypes for green pod yield per plant (2016-17)

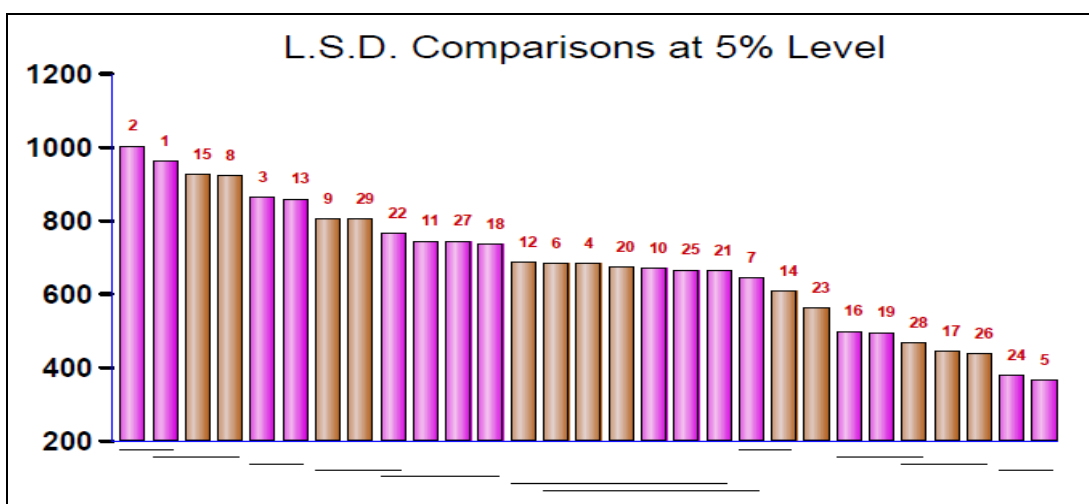


Fig. 4.20: LSD comparison of genotypes for green pod yield per plant (2017-18)

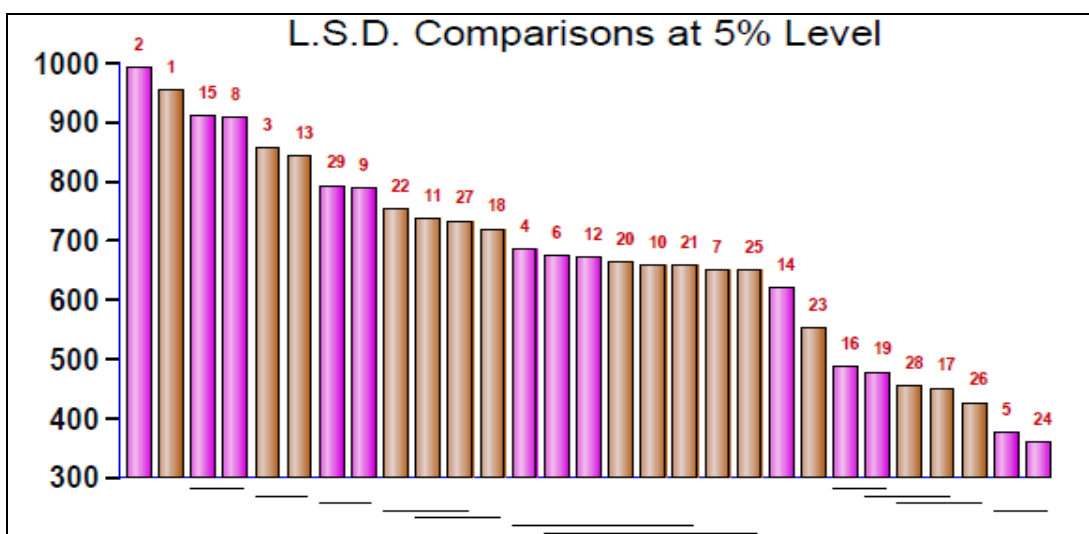


Fig. 4.21: LSD comparison of genotypes for green pod yield per plant (Pooled)

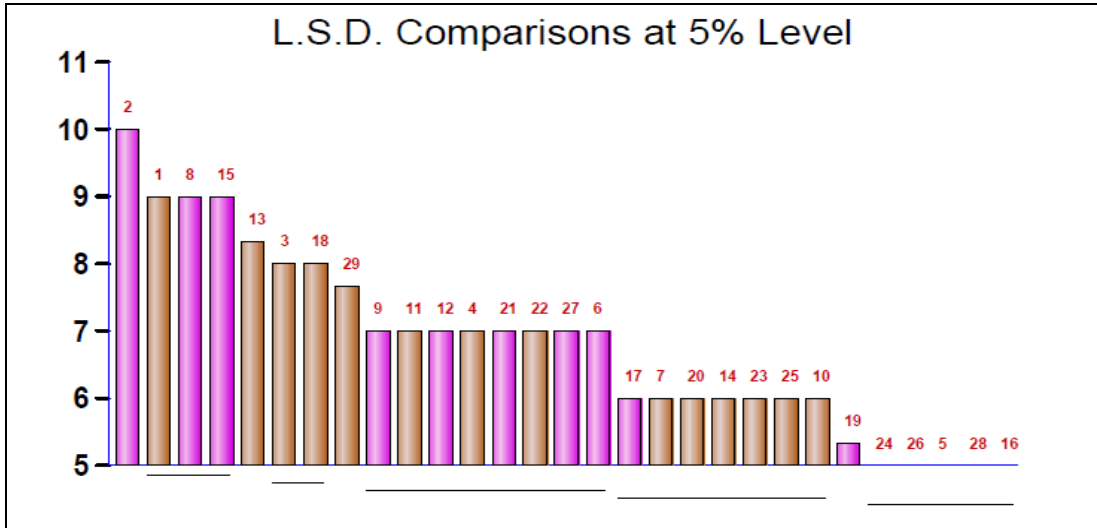


Fig. 4.22: LSD comparison of genotypes for number of pickings (2016-17)

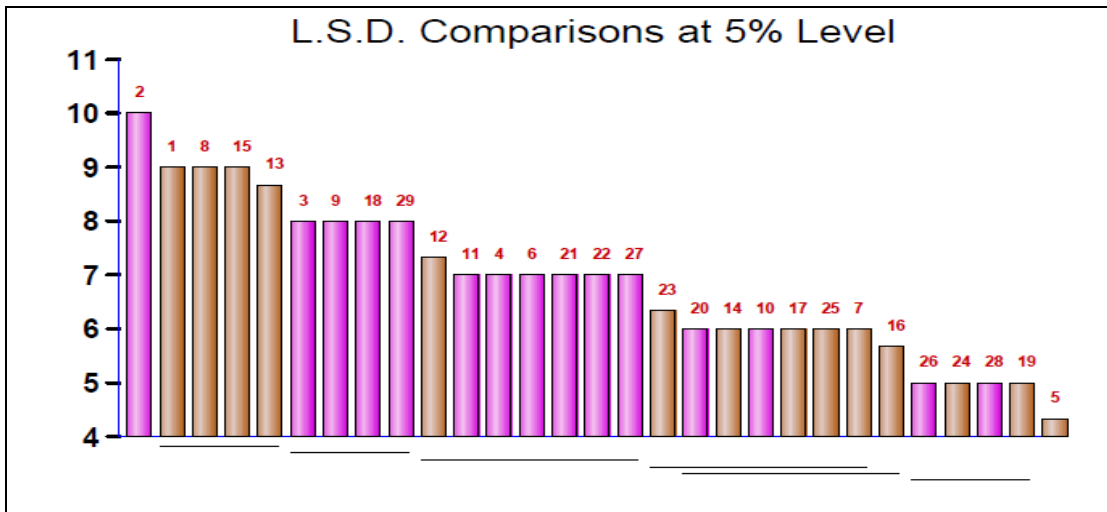


Fig. 4.23: LSD comparison of genotypes for number of pickings (2017-18)

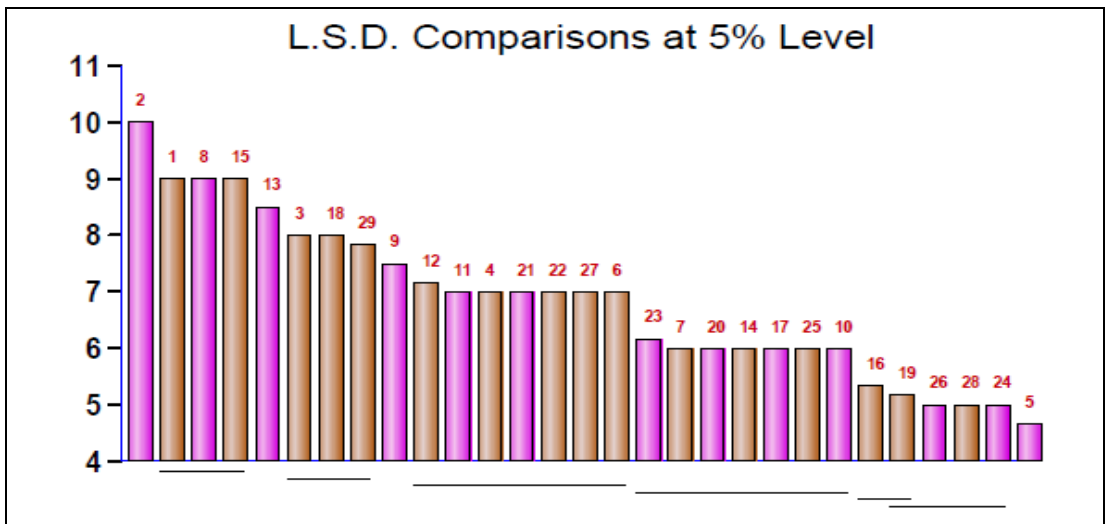


Fig. 4.24: LSD comparison of genotypes for number of pickings (Pooled)

minimum pickings of 5.00 were observed in genotype FBK-5, FBK-17, Titra Mitra and FBK-15 which were statistically at par with each other. During 2017-18, maximum pickings were observed in Lakshmi (10.00) which was significantly higher than all the genotypes and check 'Kentucky Wonder' (Fig 4.23). However, minimum pickings were observed in Titra Mitra (4.33) followed by FBK-17 (5.00), FBK-15 (5.00) and FBK-5 (5.67).

The pooled data of both years revealed that maximum number of pickings were recorded in Lakshmi (10.00) significantly higher than all other genotypes (Fig 4.24). Minimum number of pickings were observed for Titra Mitra (4.67) closely followed by FBK-13 (5.00) which were statistically at par with each other.

#### **4.1.9 Harvesting span**

The data showed that harvesting span recorded significant variation among all genotypes over both years. The harvesting span varied from 31.00 days to 59.67 days during 2016-17 and 30.00 days to 61.33 days during 2017-18 (Table 6). During 2016-17, the harvesting span was observed maximum in genotype Lakshmi (59.67 days) which was significantly higher than all genotypes and check (57.00 days). Minimum harvesting span was observed for genotype FBK-13 (31.00 days) followed by Titra Mitra (31.67 days) and FBK-8 (33.00 days) which were statistically at par with each other (Fig 4.25). During 2017-18, maximum harvesting span was observed for genotype Lakshmi (61.33 days) which was significantly higher than all other genotypes including check 'Kentucky Wonder' (Fig 4.26). Minimum harvesting span was observed for genotype FBK-8 (30.00 days) which was closely followed by Titra Mitra (30.67 days) and FBK-13 (32.00 days) which were statistically at par with each other.

The pooled data analysis of both years revealed that maximum harvesting span was observed for genotype Lakshmi (60.50 days) which was significantly higher than all other genotypes and check 'Kentucky Wonder' (56.00 days). The minimum harvesting span was observed for genotype 'Titra Mitra' (31.17 days) followed by FBK-8 (31.50 days) and FBK-13 (31.50 days) which were statistically at par with each other (Fig 4.27).

#### **4.2.1 Dry matter (%)**

The perusal of data showed significant differences were observed among all the genotypes for dry matter. The data varied from 7.40% to 13.84% during 2016-17 whereas 7.11% to 13.91% among genotypes during 2017-18 (Table 6). During 2016-17, maximum dry matter was recorded in genotype FBK-13 (13.84%) followed by FBK-5 (13.22%) which were statistically at par with each other and significantly higher than other genotypes and the check 'Kentucky Wonder' (Fig 4.28). The minimum dry matter was recorded in genotype FBB Var-1 (7.40%) followed by genotype FBK-7 (7.41%) and FBK-8 (7.80%) which were statistically at par with each other. During 2017-18, the maximum dry matter was recorded in genotype

**Table 6: Mean values of genotypes for harvesting span (days) and dry matter (%)**

Sr no	Genotypes	Harvesting span (days)			Dry matter (%)		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	55.33	55.00	55.17	10.48	10.93	10.70
2	Lakshmi	59.67	61.33	60.50	9.66	9.78	9.72
3	Kentucky Blue	44.33	47.33	45.83	9.52	9.60	9.56
4	Stringless Blue Lake	40.00	42.33	41.17	8.92	9.47	9.20
5	Titra Mitra	31.67	30.67	31.17	11.91	11.76	11.83
6	AVT Var-1	42.00	43.33	42.67	8.21	8.23	8.22
7	AVT Var-2	35.00	36.00	35.50	8.29	8.89	8.59
8	AVT Var-3	53.00	56.33	54.67	9.26	9.57	9.41
9	FBB Var-1	52.00	48.67	50.33	7.40	7.23	7.31
10	FBB Var-2	40.00	41.33	40.67	8.85	8.46	8.65
11	FBB Var-3	45.00	45.33	45.17	8.95	9.12	9.04
12	FBB Var-4	49.67	54.00	51.83	9.19	8.73	8.96
13	FBK-1	53.67	55.33	54.50	9.83	9.60	9.72
14	FBK-3	36.00	37.33	36.67	8.44	8.41	8.42
15	FBK-4	56.00	57.00	56.50	11.59	11.34	11.46
16	FBK-5	38.67	41.33	40.00	13.22	13.80	13.51
17	FBK-6	39.00	40.00	39.50	12.26	13.11	12.68
18	FBK-7	50.00	50.00	50.00	7.41	7.11	7.26
19	FBK-8	33.00	30.00	31.50	7.80	7.90	7.85
20	FBK-9	41.00	45.33	43.17	11.35	11.61	11.48
21	FBK-10	43.00	43.67	43.33	10.38	10.21	10.29
22	FBK-11	43.67	40.67	42.17	9.21	9.09	9.15
23	FBK-12	34.00	35.00	34.50	12.84	12.96	12.90
24	FBK-13	31.00	32.00	31.50	13.84	13.91	13.87
25	FBK-14	38.67	39.33	39.00	12.22	12.79	12.50
26	FBK-15	35.00	36.67	35.83	10.23	9.91	10.07
27	FBK-16	51.00	51.00	51.00	10.41	10.44	10.42
28	FBK-17	36.67	35.00	35.83	12.67	13.57	13.12
29	Kentucky Wonder (C)	57.00	55.00	56.00	9.91	10.06	9.98
<b>Grand Mean</b>		43.62	44.36	43.99	10.15	10.26	10.20
<b>CV</b>		6.23	6.68	6.56	5.05	6.05	5.36
<b>CD</b>		2.16	2.20	2.44	0.84	1.01	0.63
<b>Range</b>		31.00-59.67	30.00-61.33	31.17-60.50	7.41-13.84	7.11-13.91	7.26-13.87

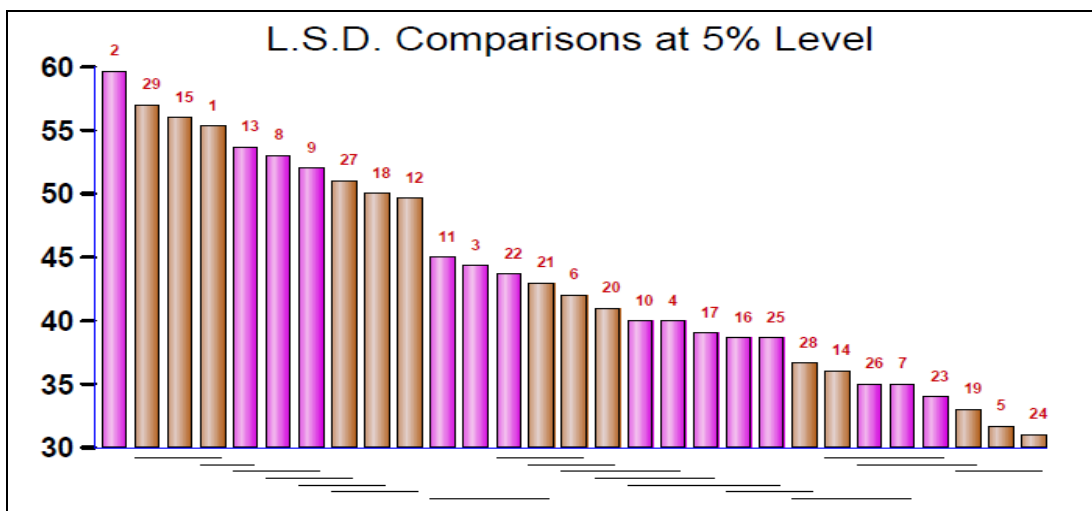


Fig. 4.25: LSD comparison of genotypes for harvesting span (2016-17)

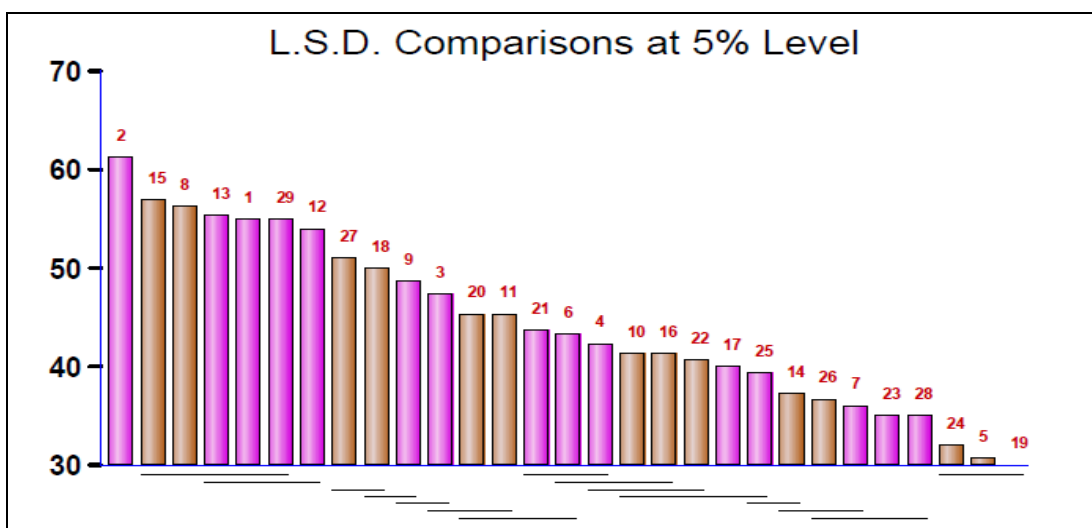


Fig. 4.26: LSD comparison of genotypes for harvesting span (2017-18)

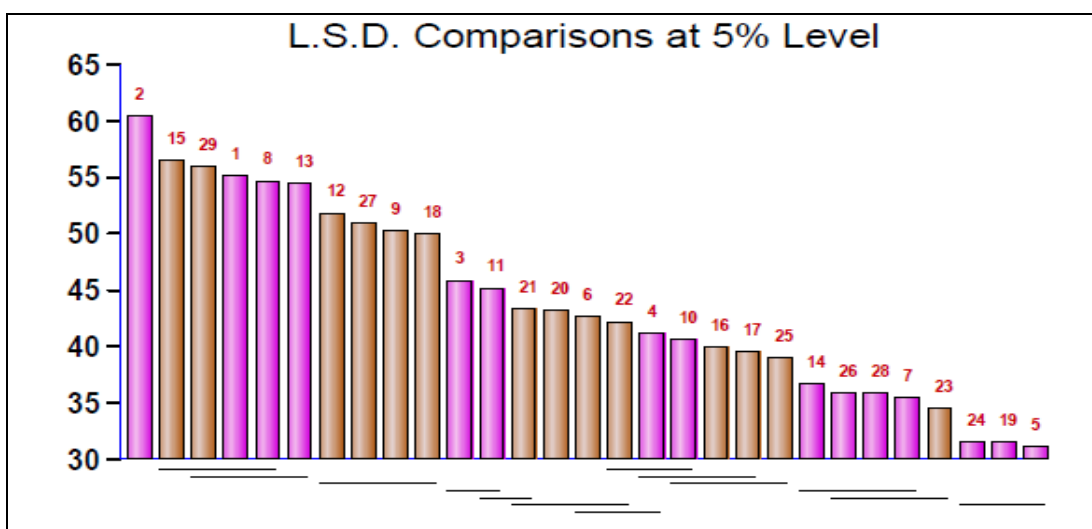


Fig. 4.27: LSD comparison of genotypes for harvesting span (Pooled)

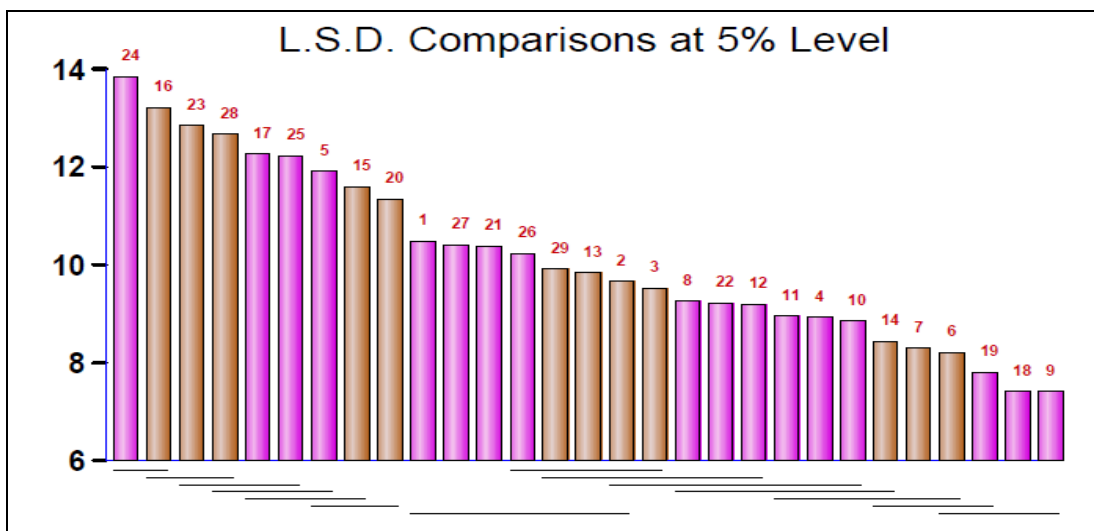


Fig. 4.28: LSD comparison of genotypes for dry matter (2016-17)

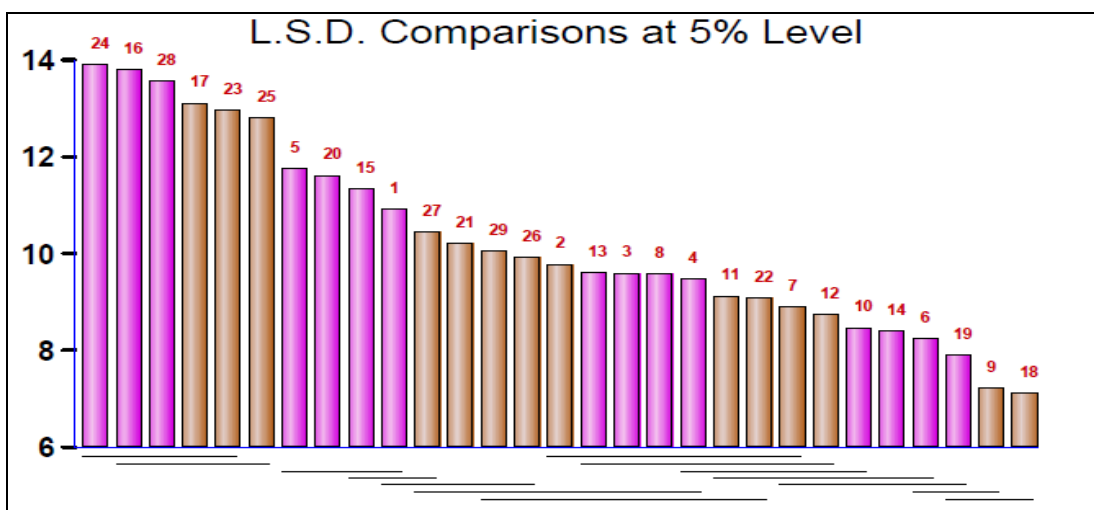


Fig. 4.29: LSD comparison of genotypes for dry matter (2017-18)

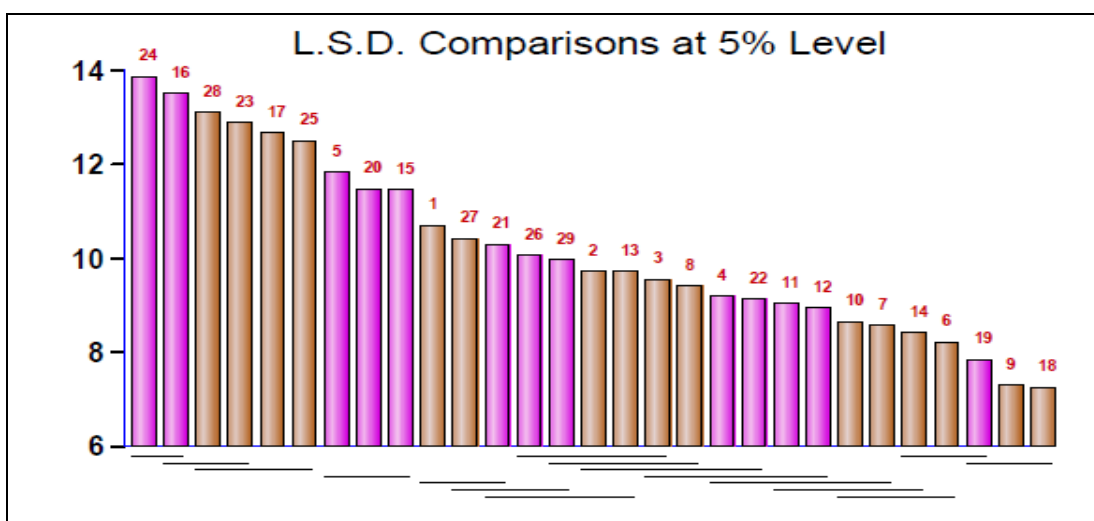


Fig. 4.30: LSD comparison of genotypes for dry matter (Pooled)

FBK-13 (13.91%) followed by FBK-5 (13.80%) which were statistically at par with each other and significantly higher than all other genotypes and check 'Kentucky Wonder'. The minimum dry matter was recorded in FBB Var-1 (7.23%) closely followed by FBK-7 (7.11%) which were statistically at par with each other (Fig 4.29).

The pooled data analysis of both years showed that maximum dry matter was recorded in genotype FBK-13 (13.87%) closely followed by FBK-5 (13.51%) which were statistically at par with each other and significantly higher than all other genotypes and check. The minimum dry matter was recorded in genotype FBK-7 (7.26%) closely followed by FBB Var-1 (7.31%) which were statistically at par with each other (Fig 4.30). The results are in accordance with study of Bandale *et al* (2004), Verma *et al* (2014) and Meena and Dhillon (2017).

#### **4.2.2 Protein content (%)**

Protein content is one of most important biochemical trait of quality pods. The analysis data revealed that protein content showed significant variation among all genotypes during both years. The protein content varied from 4.36% to 9.75% during 2016-17, 4.24% to 9.60% during 2017-18 and 4.30% to 9.67% over pooled years (Table 7). During 2016-17, maximum protein content was recorded in genotype FBK-1 (9.75%) followed by Titra Mitra (9.69 %) which were statistically at par with each other and significantly higher than rest of genotypes including check 'Kentucky Wonder'. The minimum amount of protein content was recorded in genotype FBK-8 (4.36%) which was significantly different from all other genotypes (Fig 4.31). During 2017-18, maximum protein content was recorded in genotype FBK-1 (9.60%) closely followed by Titra Mitra (9.39%) which were statistically at par with each other and significantly higher than rest of genotypes including check 'Kentucky Wonder'. Minimum protein content was recorded in genotype FBK-8 (4.24%) which was significantly different from all other genotypes (Fig 4.32).

The pooled data analysis of both years showed that maximum protein content was recorded in genotype FBK-1 (9.67%) closely followed by Titra Mitra (9.54%) which were statistically at par with each other and significantly higher than check and all other genotypes. The minimum protein content was recorded in genotype FBK-8 (4.30%) which was significantly different from other genotypes (Fig 4.33). The results are supported by the studies of Noor *et al* (2014) and Meena and Dhillon (2017).

#### **4.2.3 Sugar content (%)**

The significant variation was observed among all the genotypes for sugar content in both the years (Table 7). During 2016-17, sugar content varied from 4.27% to 9.62% whereas 4.42% to 9.73% during 2017-18. During 2016-17, the maximum sugar content was recorded in genotype FBK-5 (9.62%) followed by AVT Var-2 (9.49%) and FBK-15 (9.36%) which

**Table 7: Mean values of genotypes for protein content (%) and sugar content (%)**

Sr no	Genotypes	Protein content (%)			Sugar content (%)		
		2016-17	2017-18	Pooled Mean	2016-17	2017-18	Pooled Mean
1	Star-1	5.95	5.34	5.64	5.47	5.61	5.64
2	Lakshmi	6.23	6.48	6.35	5.65	5.74	5.69
3	Kentucky Blue	7.15	7.35	7.25	4.63	4.66	4.64
4	Stringless Blue Lake	8.49	8.34	8.41	5.15	5.31	5.23
5	Titra Mitra	9.69	9.39	9.54	6.38	6.50	6.44
6	AVT Var-1	7.33	7.52	7.43	8.40	8.51	8.46
7	AVT Var-2	6.69	7.09	6.89	9.49	9.57	9.53
8	AVT Var-3	6.08	5.92	6.00	6.41	6.78	6.60
9	FBB Var-1	5.81	5.84	5.83	8.85	9.00	8.92
10	FBB Var-2	5.07	5.10	5.09	7.45	7.77	7.61
11	FBB Var-3	4.94	5.06	5.00	8.19	8.34	8.27
12	FBB Var-4	7.86	8.00	7.93	7.46	7.53	7.50
13	FBK-1	9.75	9.60	9.67	6.25	6.13	6.19
14	FBK-3	8.89	8.74	8.81	4.27	4.42	4.35
15	FBK-4	7.96	8.04	8.00	8.35	8.42	8.38
16	FBK-5	6.02	6.06	6.04	9.62	9.73	9.67
17	FBK-6	5.85	5.74	5.79	7.62	7.97	7.79
18	FBK-7	4.92	4.75	4.84	8.90	8.84	8.87
19	FBK-8	4.36	4.24	4.30	8.87	8.63	8.75
20	FBK-9	6.15	5.96	6.05	7.41	7.47	7.44
21	FBK-10	5.75	5.23	5.49	6.39	6.56	6.48
22	FBK-11	5.37	5.53	5.45	7.14	7.39	7.26
23	FBK-12	8.91	8.87	8.89	7.48	7.56	7.52
24	FBK-13	6.75	6.70	6.72	8.38	8.16	8.27
25	FBK-14	6.92	6.86	6.89	9.10	9.03	9.07
26	FBK-15	8.13	8.04	8.08	9.36	8.87	9.11
27	FBK-16	7.74	7.64	7.69	6.31	6.52	6.42
28	FBK-17	6.98	7.04	7.01	5.45	5.41	5.43
29	Kentucky wonder (C)	7.79	7.38	7.58	7.50	7.44	7.47
<b>Grand Mean</b>		6.88	6.82	6.85	7.31	7.37	7.34
<b>CV</b>		3.05	4.22	3.89	2.64	3.44	3.06
<b>CD</b>		0.34	0.37	0.27	0.32	0.42	0.26
<b>Range</b>		4.36-9.75	4.24-9.60	4.30-9.67	4.27-9.62	4.27-9.73	4.35-9.67

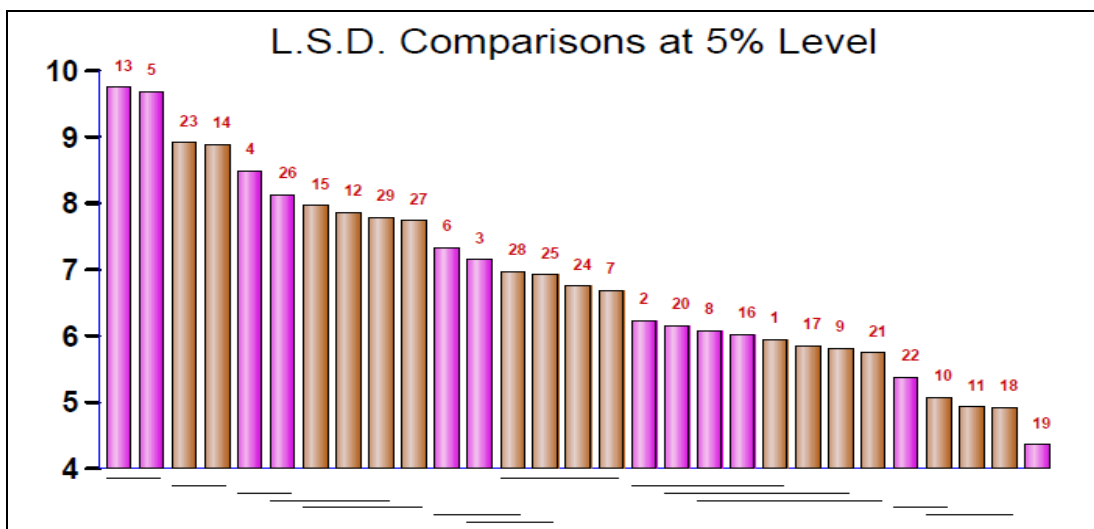


Fig. 4.31: LSD comparison of genotypes for protein content (2016-17)

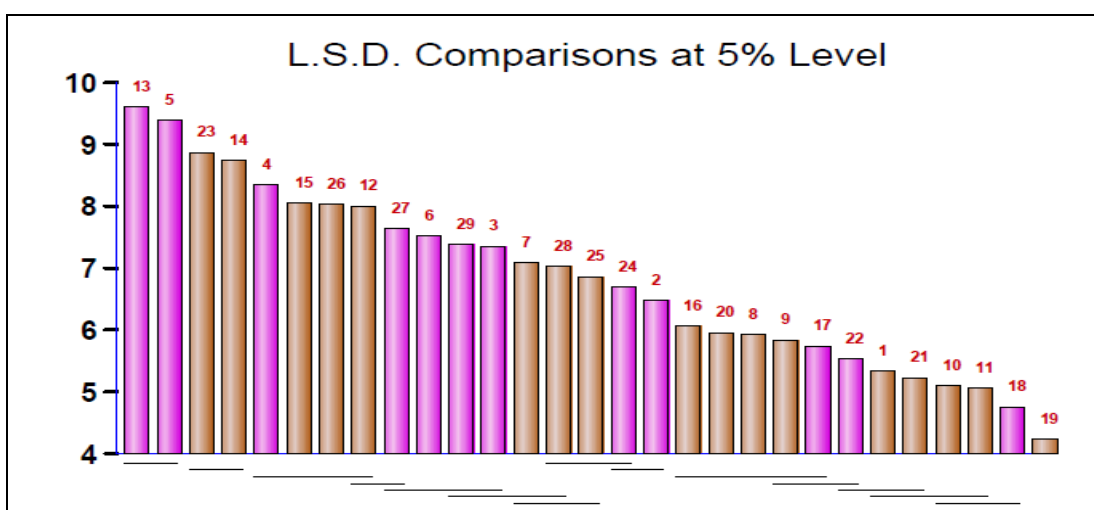


Fig. 4.32: LSD comparison of genotypes for protein content (2017-18)

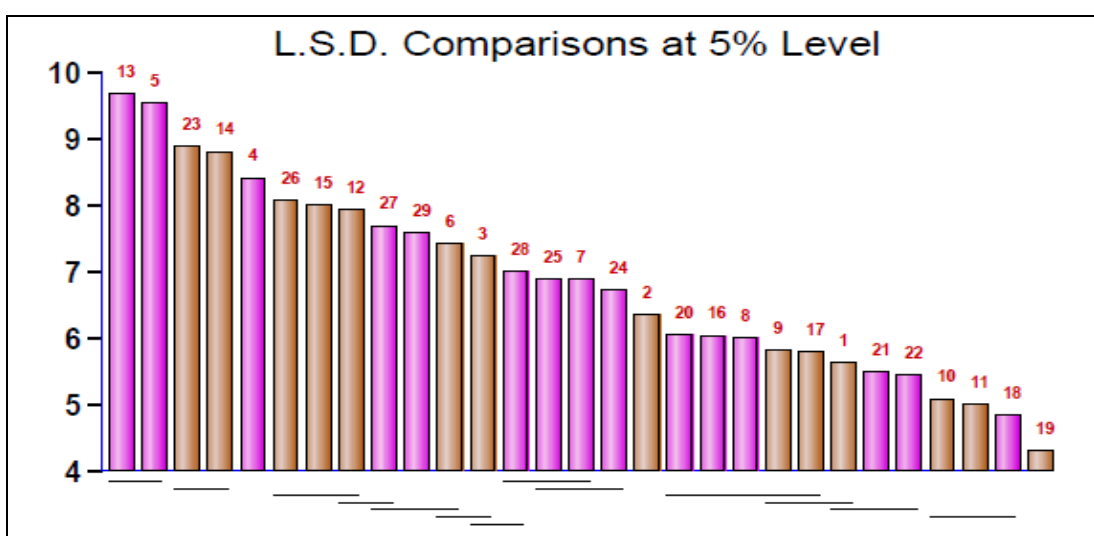


Fig. 4.33: LSD comparison of genotypes for Protein content (Pooled)

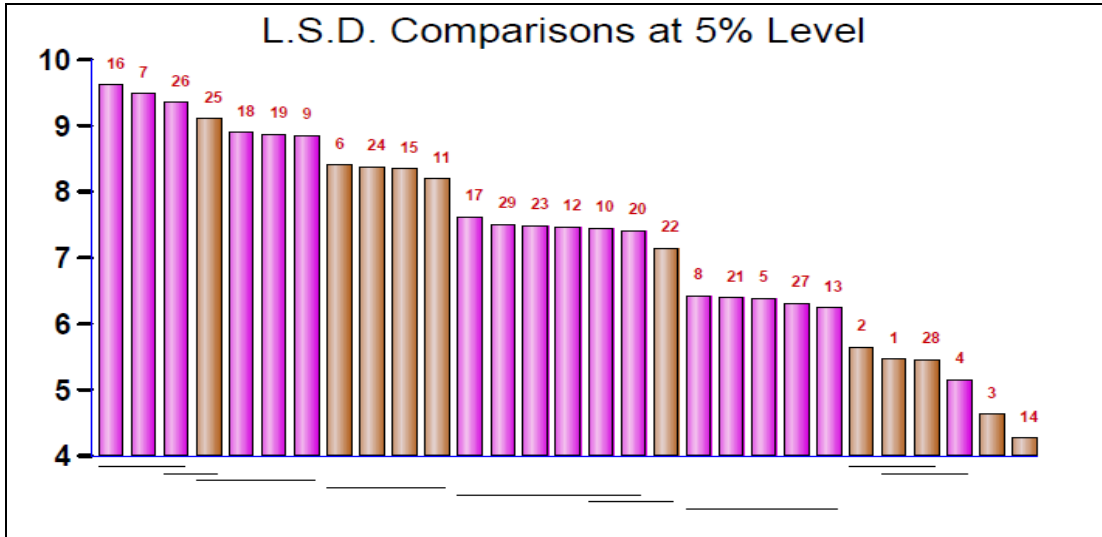


Fig. 4.34: LSD comparison of genotypes for sugar content (2016-17)

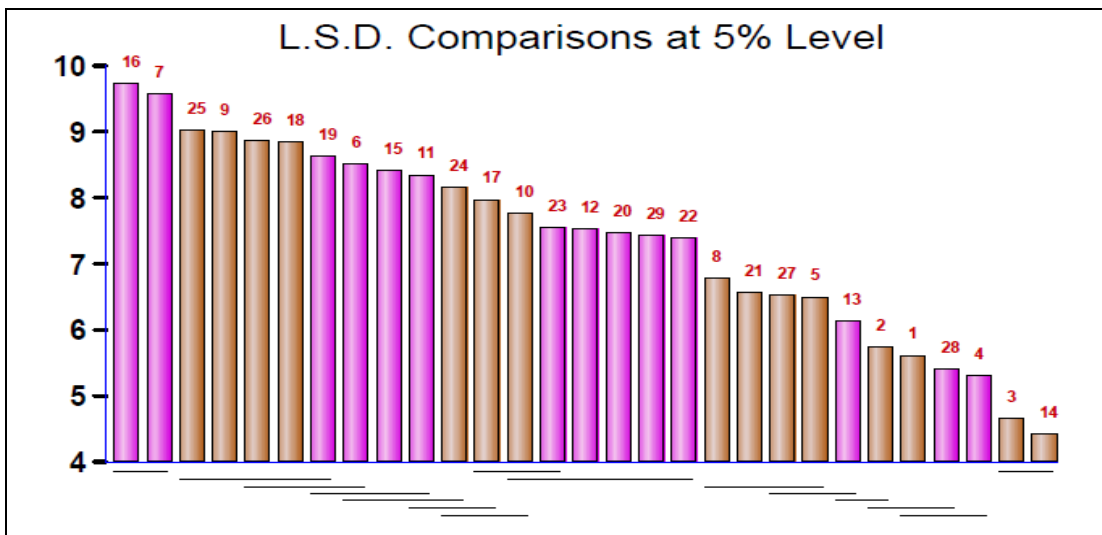


Fig. 4.35: LSD comparison of genotypes for sugar content (2017-18)

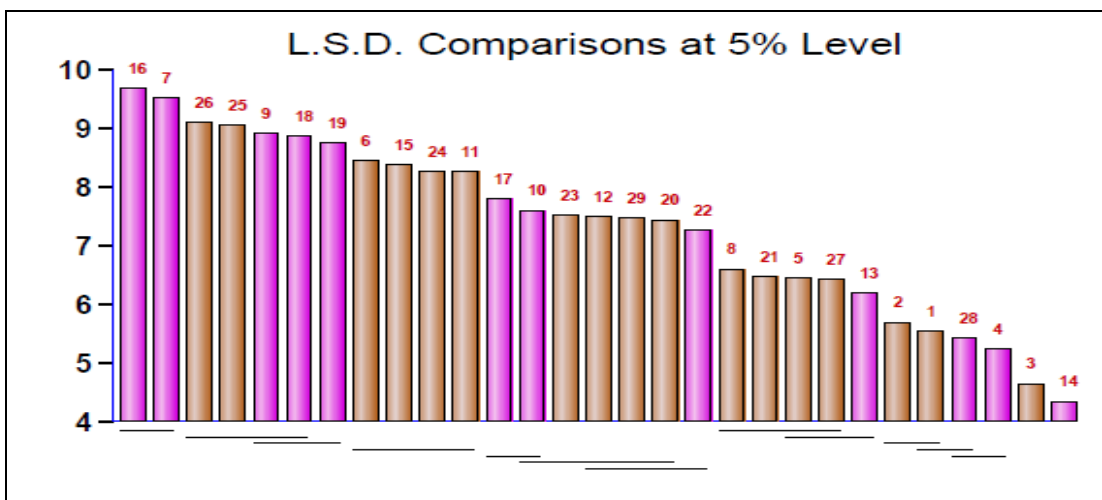


Fig. 4.36: LSD comparison of genotypes for sugar content (Pooled)

were statistically at par with each other and significantly higher than rest of genotypes and check 'Kentucky Wonder' (Fig 4.34). The minimum sugar content was observed for genotype FBK-3 (4.27%) followed by Kentucky Blue (4.63%) which were statistically at par with each other. During 2017-18, higher level of sugar was observed in genotype FBK-5 (9.73%) closely followed by AVT Var-2 (9.57%) which were closely at par with each other and significantly higher than rest of genotypes. The lower value of sugar was recorded in genotype FBK-3 (4.42%) and Kentucky Blue (4.66%) which were statistically at par with each other (Fig 4.35).

The pooled data analysis of both years showed that the maximum sugar content was recorded in genotype FBK-5 (9.67%) followed by genotype AVT Var-2 (9.53%) which were statistically at par with each other and significantly higher than other genotypes and check 'Kentucky Wonder' (Fig 4.36). The lower values of sugar content was observed in genotype FBK-3 (4.35%) which was statistically at par with genotype Kentucky Blue (4.64%) and significantly different from other genotypes. The present findings are in agreement with investigations carried by Parkash *et al* (2011) and Meena and Dhillon (2017).

#### **4.2.4 Fibre content (%)**

The significant variation was observed among all the genotypes for fibre content during both years (Table 8). The fibre content varied from 0.68% to 1.36% during 2016-17 whereas it varied from 0.70% to 1.44% during 2017-18. During 2016-17, genotype FBB Var-4 (0.68%) showed the lowest fibre content which was statistically at par with genotype FBK-12 (Fig 4.37). However, fibre content was recorded maximum in genotype FBK-15 (1.36%) followed by genotype AVT Var-1 (1.25%) and genotype FBK-3 (1.22%) which were statistically at par with each other but significantly higher than rest of the genotypes including check. The data evaluation during 2017-18 showed that minimum fibre content was observed in genotype FBK-12 (0.70%) which was statistically at par with genotypes FBB Var-4 (0.77%), Stringless Blue Lake (0.77%) and AVT Var-2 (0.79%) whereas maximum fibre content was recorded in genotype FBK-15 (1.44%) which was statistically at par with genotype FBK-3 (1.28%) and significantly higher than check 'Kentucky Wonder' (Fig 4.38).

The pooled data analysis of both years showed that the minimum fibre content was observed in FBK-12 (0.69%) which was statistically at par with FBB Var-4 (0.72%) whereas maximum fibre content was observed in genotype FBK-15 (1.40%) which was statistically at par with FBK-3 (1.25%) significantly higher than rest of genotypes and check 'Kentucky Wonder' (Fig 4.39). These results are in conformity with studies of Verma *et al* (2014) and Meena and Dillon (2017).

**Table 8: Mean values of genotypes for fibre content (%)**

Sr no	Genotypes	Fibre content (%)		
		2016-17	2017-18	Pooled Mean
1	Star-1	1.04	1.06	1.05
2	Lakshmi	0.82	0.85	0.83
3	Kentucky Blue	0.79	1.10	0.94
4	Stringless Blue Lake	0.77	0.77	0.77
5	Titra Mitra	1.05	0.99	1.02
6	AVT Var-1	1.25	1.15	1.20
7	AVT Var-2	0.80	0.79	0.79
8	AVT Var-3	0.79	0.82	0.80
9	FBB Var-1	0.80	0.89	0.85
10	FBB Var-2	1.13	1.09	1.11
11	FBB Var-3	1.01	1.05	1.03
12	FBB Var-4	0.68	0.77	0.72
13	FBK-1	0.82	0.98	0.90
14	FBK-3	1.22	1.28	1.25
15	FBK-4	0.91	0.98	0.95
16	FBK-5	1.08	1.07	1.07
17	FBK-6	1.19	1.17	1.18
18	FBK-7	0.81	0.97	0.89
19	FBK-8	0.81	0.85	0.83
20	FBK-9	0.98	1.03	1.00
21	FBK-10	0.99	1.01	1.00
22	FBK-11	0.91	0.98	0.95
23	FBK-12	0.68	0.70	0.69
24	FBK-13	1.02	1.03	1.03
25	FBK-14	1.12	1.07	1.10
26	FBK-15	1.36	1.44	1.40
27	FBK-16	1.14	1.06	1.10
28	FBK-17	0.96	0.98	0.97
29	Kentucky Wonder (C)	0.96	0.99	0.97
<b>Grand mean</b>		0.96	1.00	0.98
<b>CV</b>		5.74	6.00	6.92
<b>CD</b>		0.09	0.10	0.08
<b>Range</b>		0.68-1.36	0.70-1.44	0.69-1.40

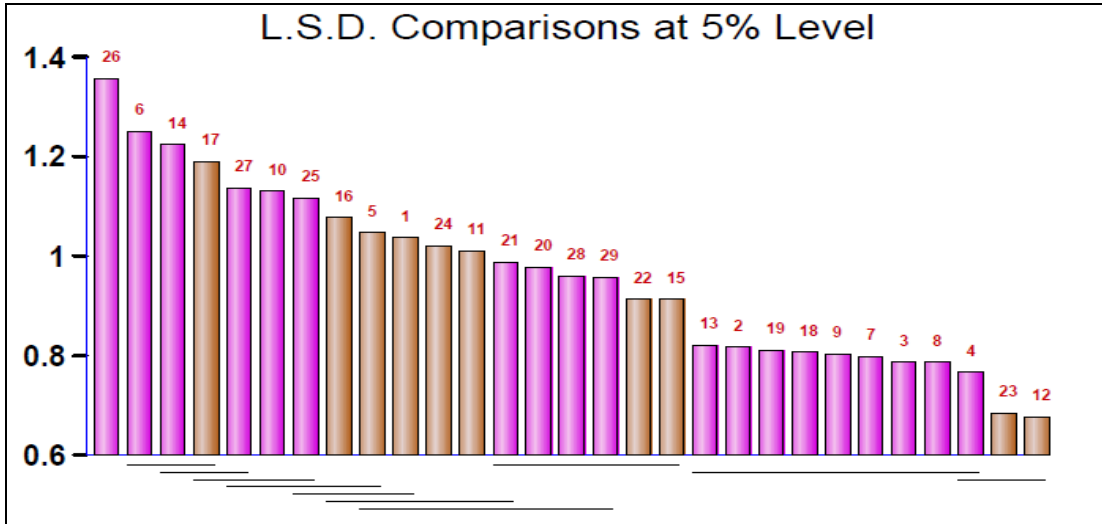


Fig. 4.37: LSD comparison of genotypes for fibre content (2016-17)

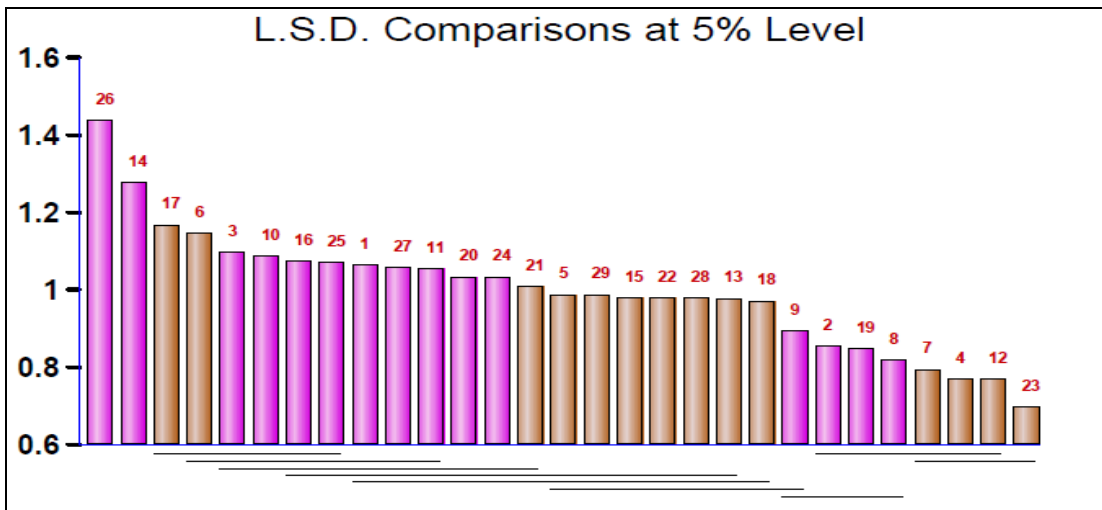


Fig. 4.38: LSD comparison of genotypes for fibre content (2017-18)

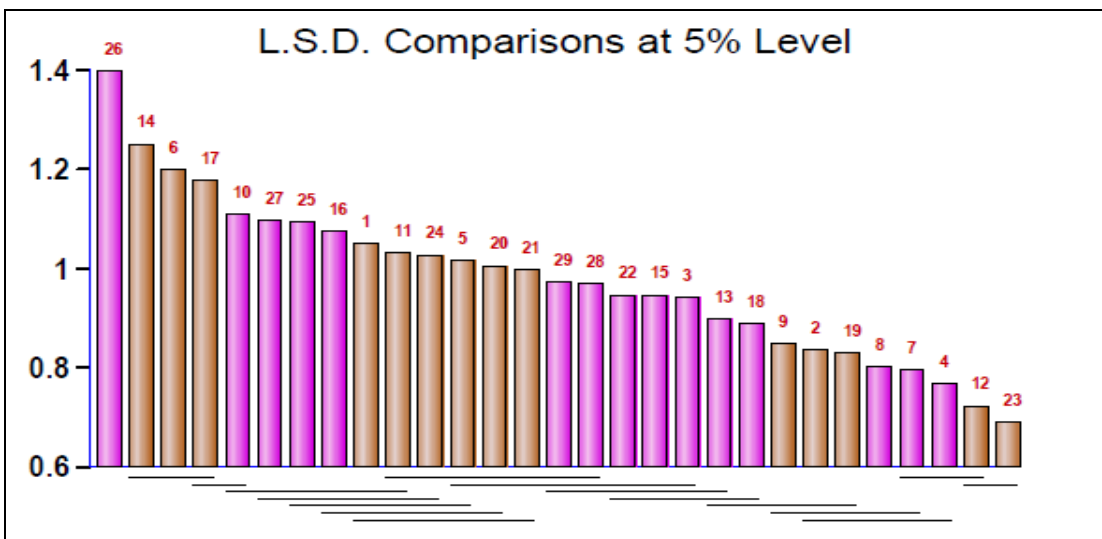


Fig. 4.39: LSD comparison of genotypes for fibre content (Pooled)

**Table 9: Pod shape and colour of different genotypes of French bean**

<b>S. No.</b>	<b>Genotypes</b>	<b>Pod characters and colour</b>
1.	Star-1	Round, slightly curved and light green
2.	Lakshmi	Round, straight and dark green
3.	Kentucky Blue	Round, straight and green
4.	Stringless Blue Lake	Round, straight and dark green
5.	Titra Mitra	Flat, straight and light green
6.	AVT Var-1	Round, straight and purple
7.	AVT Var-2	Round, straight and light green
8.	AVT Var-3	Round, straight and green
9.	FBB Var-1	Round, straight and purple
10.	FBB Var-2	Round, slightly curved and light green
11.	FBB Var-3	Round, straight and green
12.	FBB Var-4	Round, slightly curved and purple
13.	FBK-1	Round, straight and dark green
14.	FBK-3	Flat, curved and light green
15.	FBK-4	Flat, straight and green
16.	FBK-5	Flat, slightly curved and light green
17.	FBK-6	Flat, curved and green
18.	FBK-7	Flat, slightly curved and light green
19.	FBK-8	Round, straight and green
20.	FBK-9	Flat, slightly curved and green
21.	FBK-10	Flat, slightly curved and light green
22.	FBK-11	Flat, straight and green
23.	FBK-12	Round, slightly curved and green
24.	FBK-13	Flat, slightly curved and light green
25.	FBK-14	Flat, slightly curved and light green
26.	FBK-15	Flat, curved and dark green
27.	FBK-16	Flat, straight and green
28.	FBK-17	Flat, curved and green
29.	Kentucky Wonder (C)	Flat, slightly curved and green



**FBB Var-2**

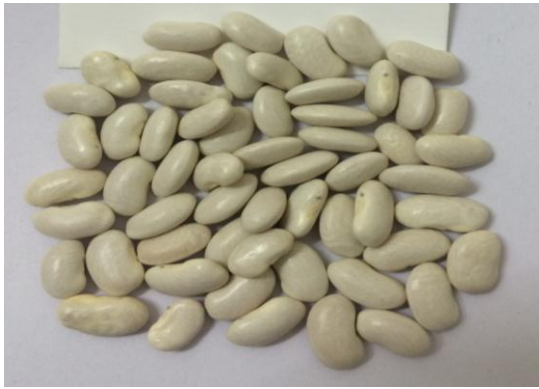


**Kentucky Blue**



**FBB Var-1**

**Plate 1: Variability in pod colour of different genotypes of French bean**



**Star-1**



**Titra Mitra**



**FBK-1**



**FBB Var-2**



**FBK-3**



**FBB Var-4**



**FBK-12**



**FBK-13**

**Plate 2: Variability in seed colour of different genotypes of French bean**



**Plate 3: Performance of French bean genotypes in poly-net house**

## **4.2 Analysis of variance**

From the analysis of variance, it was observed that mean squares due to genotypes were significant for all the traits studied during 2016-17 (Table 10), 2017-18 (Table 11) and pooled mean (Table 12).

### **4.2.1 Components of variation**

The range of mean values based on phenotypic expression could represent only a rough estimate of the variation or magnitude of divergence present among different genotypes. As the estimates of phenotypic variability cannot differentiate between genetic and environmental effects, so the phenotypic or observed variation was partitioned into heritable (variation due to genotype) and non-heritable (variation due to environment). The results pertaining to the phenotypic and genotypic coefficient of variation have been presented in (Table 13, 14, 15). A relative amount of variation in the genotypes for different characters can be judged by comparing the coefficient of genotypic and phenotypic variation.

#### **4.2.1.1 Phenotypic coefficient of variation (%)**

The phenotypic coefficient of variation (PCV) was higher than the respective genotypic coefficient of variation for all the traits under study which showed the influence of environment on these traits. The data indicated significant range of phenotypic variability in the experimental material. During 2016-17, PCV was high for green pod yield per plant (25.96%) followed by number of pods per plant (22.42%), protein content (21.20%), sugar content (20.89%) and number of pickings (20.50%). The estimates were moderate for harvesting span (19.48%), fibre content (19.03%), dry matter (18.24%), pod weight (15.48%), days to 50% flowering (12.65%), pod length (12.59%) and pod width (12.08%) while low for days to first harvest (6.66%) (Table 13).

During 2017-18, PCV was high for green pod yield per plant (25.81%) followed by number of pods per plant (22.11%), protein content (21.36%), number of pickings (21.26%) and sugar content (20.10%). The estimates were moderate for dry matter (19.86%), harvesting span (19.76%), fibre content (19.03%), pod weight (17.16%), fibre content (16.48%), pod length (14.18%), days to 50% flowering (12.92%) and pod width (10.77%) while low for days to first harvest (6.46%) (Table 14). The pooled data of both years showed that the PCV was high for green pod yield per plant (25.89%) followed by number of pods per plant (22.26%), protein content (21.28%), number of pickings (20.89%) and sugar content (20.49%). The estimates were moderate for harvesting span (19.63%), dry matter (19.08%), fibre content (17.76%), pod weight (16.35%), pod length (13.36%), days to 50% flowering (12.79%) and pod width (11.44%) while low for days to first harvest (6.56%) (Table 15). Phenotypic coefficient of variation expresses the gross variation i.e.

**Table 10: Analysis of variance for different characters in French bean (2016-17)**

Source of variation	Df	Days to 50% flowering	Days to first harvest	Number of pods/ plant	Pod weight	Pod length	Pod width	Green pod yield per plant	Number of pickings	Harvesting Span	Dry matter content	Protein content	Sugar content	Fibre content
Replication	2	2.25	7.04	67.05	0.51	0.52	0.00	180.24	0.08	1.48	0.03	0.00	0.04	0.01
Genotypes	28	281.19**	172.39**	1655.82**	1.88**	6.59**	0.02**	87574.41**	5.77**	213.14**	9.75**	6.28**	6.92**	0.09**
Error	56	1.72	3.71	132.72	0.40	0.46	0.00	827.06	0.03	1.74	0.26	0.05	0.04	0.00

\*\*Significant at both 5% and 1% respectively

**Table 11: Analysis of variance for different characters in French bean (2017-18)**

Source of variation	Df	Days to 50% flowering	Days to first harvest	Number of pods/ plant	Pod weight	Pod length	Pod width	Green pod yield per plant	Number of pickings	Harvesting Span	Dry matter content	Protein content	Sugar content	Fibre content
Replication	2	1.18	1.53	219.73	0.18	0.27	0.01	380.15	0.08	3.18	0.88	0.01	0.04	0.00
Genotypes	28	302.19**	169.18**	1738.89**	2.93**	7.60**	0.02**	91621.18**	6.29**	226.95**	11.68**	6.27**	6.46**	0.09**
Error	56	1.43	2.74	97.97	0.21	0.36	0.00	605.72	0.06	1.80	0.38	0.05	0.06	0.00

\*\*Significant at both 5% and 1% respectively

**Table 12: Analysis of variance for different characters in French bean (Pooled)**

Source of variation	Df	Days to 50% flowering	Days to first harvest	Number of pods/plant	Pod weight	Pod length	Pod width	Green pod yield per plant	Number of pickings	Harvesting Span	Dry matter content	Protein content	Sugar content	Fibre content
Replication	2	1.77	2.40	93.77	0.04	0.38	0.01	491.68	0.04	3.45	0.62	0.01	0.08	0.00
Genotypes	28	572.07**	331.35**	3204.19**	4.34**	13.80**	0.03**	178802.81**	11.95**	434.13**	21.24**	12.48**	13.33**	0.16**
Enviornments	1	0.28	2.78	170.02	0.12	29.01	0.00	12965.54**	0.21	23.54	0.57	0.14	0.20	0.11
Interaction	2	0.59	0.04	407.00*	0.66	0.41	0.03	68.71	0.12	1.21	0.29	0.00	0.00	0.00
Error	140	3.52	4.62	130.38	0.34	0.40	0.01	651.67	0.06	2.61	0.30	0.05	0.05	0.00

\*\*Significant at both 5% and 1% respectively

due to genotype and environment variation existing in the material. The results are supported by the studies of Chaudhary and Sharma (2003), Devi *et al* (2015) and Topwal and Gaur (2016).

#### **4.2.1.2 Genotypic coefficient of variation (%)**

Selection purely based on the phenotypic coefficient of variation is not applicable because it is affected by environment components. Therefore, it is necessary to study genotypic coefficient of variation (GCV) for better selection of all traits. In this study, during 2016-17, GCV was high for green pod yield per plant (25.60%) followed by protein content (20.95%), sugar content (20.72%) and number of pickings (20.33%). The estimates of GCV were moderate for number of pods per plant (19.96%), harvesting span (19.24%), fibre content (18.14%), dry matter (17.53%), days to 50% flowering (12.54%), pod weight (11.52%) and pod length (11.39%) while low for pod width (7.26%) and days to first harvest (6.45%) (Table 13). During year 2017-18, GCV was high for green pod yield per plant (25.56%) followed by protein content (21.10%), number of pickings (20.98%) and number of pods per plant (20.36%). The estimates of GCV were moderate for sugar content (19.80%), harvesting span (19.53%), pod weight (15.47%), fibre content (15.36%), pod length (13.24%) and days to 50% flowering (12.83) while low for pod width (6.97%) and days to first harvest (6.31%) (Table 14). The pooled data of both years showed that GCV was high for green pod yield per plant (25.16%) followed by protein content (21.00%), number of pickings (20.58%) and sugar content (20.26%). The estimates were moderate for number of pods per plant (19.88%), harvesting span (19.28%), dry matter (18.31%), fibre content (16.36%), pod weight (13.31%), days to 50% flowering (12.56%) and pod length (12.30%) while low for pod width (7.51%) and days to first harvest (6.30%) (Table 15). The present findings are in agreement with investigations carried by Devi *et al* (2015) and Kumar *et al* (2014).

In all the traits, GCV were less than the corresponding PCV, indicating role of environment in the expression of all the traits. The differences between genotypic and phenotypic coefficient of variation were more in case of number of pods per plant, pod weight and pod width. These large differences between genotypic and phenotypic coefficient of variation indicated that these traits were influenced by environmental effects to a large extent. These environmental effects could be due to heterogeneity in fertility status or other unpredictable factors.

In the present study, there are more chances of improvement through selection in characters *viz.* green pod yield per plant, number of pickings, pod weight, sugar content,

protein content, fibre content and dry matter content. There are very narrow differences between phenotypic and genotypic coefficient of variation indicating low environmental influence in expression of these characters which implies that phenotypic variability is a reliable measure of genotypic variability for these characters. So, selection for improvement of these traits is possible and effective on the phenotypic basis.

#### **4.2.1.3 Heritability in broad sense (%)**

Selection is always favoured when a major proportion of a large amount of phenotypic variability is due to heritable variation. Heritability is a measure of genetic relationship between parents and progeny and has been widely used in determining the degree to which a character may be transmitted from parents to offspring. Knowledge of the degree of heritability for the character permits a rational choice of breeding methods to be followed for its improvement and helps to estimate the genetic advance from selection.

In the present study, most of the characters showed high (>80%) to moderate heritability (60-80%) except for pod width during both the years. During 2016-17, the high estimates of heritability were obtained in case of protein content (98.00%) followed by sugar content (98.00%), days to 50% flowering (98.00%), number of pickings (98.00%), harvesting span (98.00%), green pod yield per plant (97.00%), days to first harvest (94.00%), fibre content (91.00%) and pod length (82.00%). The estimates were moderate for number of pods per plant (79.00%) whereas low for pod weight (55.00%) and pod width (36.00%) (Table 13). During 2017-18, the high heritability was observed for protein content (98.00%) followed by green pod yield per plant (98.00%), harvesting span (98.00%), number of pickings (97.00%), sugar content (97.00%), days to first harvest (95.00%), dry matter (91.00%), pod length (87.00%), fibre content (87.00%), number of pods per plant (85.00%) and pod weight (81.00%) while low for pod width (42.00%) (Table 14). The pooled analysis of both years showed high estimates of heritability were obtained in case of green pod yield per plant (98.00%) followed by sugar content (98.00%), number of pickings (97.00%), protein content (97.00%), harvesting span (96.00%), days to 50% flowering (96.00%), dry matter (92.00%), days to first harvest (92.00%), fibre content (85.00%), pod length (85.00%), number of pods per plant (80.00%). The estimates were moderate for pod weight (66.00%) where as low for pod width (43.00%) (Table 15). Similar results were also corroborated by Singh and Mir (2005), Sardana *et al* (2007), Kulkarni *et al* (2014), Patidar *et al* (2014) and Kumar *et al* (2015).

#### **4.2.1.4 Genetic advance as percentage of mean (%)**

The selection only on the heritable basis is not effective criteria for the best genotypes however the selection based on heritability along with genetic advance as per cent mean is more

effective (Rafi and Nath 2004). Improvement in the mean genotypic value of selected families over base population is known as genetic advance. Genetic advance depends upon the heritability of the character under selection, genetic variability of genotypes and intensity of selection. The genetic advance shows the improvement that can be made in a particular character by applying certain amount of selection intensity.

During 2016-17, genetic advance varied from 8.98% to 52.00% among all the traits studied (Table 13). The high genetic advance as per cent of mean was predicted in green pod yield per plant (52.00%) followed by protein content (42.65%), sugar content (42.34%), number of pickings (41.53%), harvesting span (39.16%), number of pods per plant (36.61%), fibre content (35.63%), days to 50% flowering (25.59%), pod length (21.22%), pod weight (17.66%) and days to first harvest (12.86%). Comparatively low genetic advance as per cent of mean was obtained for pod width (8.98%).

During 2017-18, genetic advance varied from 9.30% to 52.13% among all the traits studied (Table 14). The high genetic advance as per cent of mean was predicted in case of green pod yield per plant (52.13%) followed by protein content (42.92%), number of pickings (42.64%), sugar content (40.19%), harvesting span (39.76%), number of pods per plant (38.63%), dry matter (37.11%), fibre content (29.48%), pod weight (28.72%), days to 50% flowering (26.25%), pod length (25.45%) and days to first harvest (12.69%). Comparatively low genetic advance as per cent of mean was obtained for pod width (9.30%).

Genetic advance as percent of mean varied from 10.15% to 52.18% in pooled mean analysis of both years for all traits (Table 15). The high genetic advance as per cent of mean was predicted in case of green pod yield per plant (52.18%) followed by protein content (42.69%), number of pickings (41.76%), sugar content (41.27%), harvesting span (39.01%), number of pods per plant (36.56%), dry matter (36.20%), fibre content (31.03%), days to 50% flowering (25.41%), pod length (23.32%), pod weight (22.31%). Comparatively low genetic advance as per cent of mean were obtained for days to first harvest (12.46%) and pod width (10.15%).

Depending upon the variability, heritability and genetic advance (as percentage of mean), it could be predicted that improvement by direct selection was possible in French bean for traits like green pod yield per plant, protein content, number of pickings, sugar content, harvesting span and number of pods per plant. These results are in conformity with studies of Walling and Chuturvedi (2014), Devi *et al* (2015) and Prakash *et al* (2015).

**Table 13: Estimate of heritability ( $h^2$ ), genetic advance (GA) and genetic advance as percentage (GA%), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) for various characters in French bean (2016-17)**

Characters	PCV%	GCV%	$h^2$	GA	GA%	GM
Days to 50% flowering	12.65	12.54	98.00	19.70	25.59	76.98
Days to first harvest	6.66	6.45	94.00	14.96	12.86	116.30
Number of pods per plant	22.42	19.96	79.00	41.33	36.61	112.87
Pod weight	15.48	11.52	55.80	1.08	17.66	6.11
Pod length	12.59	11.39	82.00	2.66	21.22	12.56
Pod width	12.08	7.26	36.00	0.08	8.98	0.86
Green pod yield per plant	25.96	25.60	97.00	345.39	52.00	664.28
Number of pickings	20.50	20.33	98.00	2.83	41.53	6.80
Harvesting span	19.48	19.24	98.00	17.08	39.16	43.62
Dry matter	18.24	17.53	92.00	3.52	34.69	10.15
Protein content	21.20	20.95	98.00	2.93	42.65	6.88
Sugar content	20.89	20.72	98.00	3.09	42.34	7.31
Fibre content	19.03	18.14	91.00	0.34	35.63	0.96

**Table 14: Estimate of heritability ( $h^2$ ), genetic advance (GA) and genetic advance as percentage (GA%), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) for various characters in French bean (2017-18)**

<b>Characters</b>	<b>PCV%</b>	<b>GCV%</b>	<b><math>h^2</math></b>	<b>GA</b>	<b>GA%</b>	<b>GM</b>
Days to 50% flowering	12.92	12.83	99.00	20.48	26.25	78.02
Days to first harvest	6.46	6.31	95.00	14.98	12.69	118.05
Number of pods per plant	22.11	20.36	85.00	44.37	38.63	114.85
Pod weight	17.16	15.47	81.00	1.77	28.72	6.16
Pod length	14.18	13.24	87.00	2.99	25.45	11.74
Pod width	10.77	6.97	42.00	0.08	9.30	0.86
Green pod yield per plant	25.81	25.56	98.00	355.28	52.13	681.54
Number of pickings	21.26	20.98	97.00	2.93	42.64	6.87
Harvesting span	19.76	19.53	98.00	17.64	39.76	44.36
Dry matter	19.86	18.91	91.00	3.81	37.11	10.26
Protein content	21.36	21.10	98.00	2.93	42.92	6.82
Sugar content	20.10	19.80	97.00	2.96	40.19	7.38
Fibre content	16.48	15.36	87.00	0.29	29.48	1.00

**Table 15: Estimate of heritability ( $h^2$ ), genetic advance (GA) and genetic advance as percentage (GA%), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) for various characters in French bean (Pooled)**

<b>Characters</b>	<b>PCV%</b>	<b>GCV%</b>	<b><math>h^2</math></b>	<b>GA</b>	<b>GA%</b>	<b>GM</b>
Days to 50% flowering	12.79	12.56	96.00	19.69	25.41	77.50
Days to first harvest	6.56	6.30	92.00	14.59	12.46	117.17
Number of pods per plant	22.26	19.88	80.00	41.63	36.56	113.86
Pod weight	16.35	13.31	66.00	1.37	22.31	6.13
Pod length	13.36	12.30	85.00	2.83	23.32	12.15
Pod width	11.44	7.51	43.00	0.09	10.15	0.86
Green pod yield per plant	25.89	25.61	98.00	351.13	52.18	672.91
Number of pickings	20.89	20.58	97.00	2.86	41.76	6.84
Harvesting span	19.63	19.28	96.00	17.16	39.01	43.99
Dry matter	19.08	18.31	92.00	3.69	36.20	10.20
Protein content	21.28	21.00	97.00	2.92	42.69	6.85
Sugar content	20.49	20.26	98.00	3.03	41.27	7.34
Fibre content	17.76	16.36	85.00	0.30	31.03	0.98

### **4.3 Correlation coefficient and path analysis**

#### **4.3.1 Correlation coefficient**

After gaining information regarding the variability available in the present material, it was considered worthwhile to study the inter-relationship of different characters. Yield is a complex trait and is the multiplicative end product of various factors which singly or jointly affects it along with environment in which it is estimated. The study of correlation helps breeder in determination of the relationship between various characters and determines the component characters on which selection can be based for genetic improvement in yield.

A positive value of correlation shows that the changes of two variables are in the same direction i.e. high values of one variable are associated with high values of other and vice-versa. When correlation is negative, the movements are in opposite directions i.e. high values of one variable are associated with low values of other. The breeding goal always envisages high expression of all or most of the desirable traits in single genotype. In view of this, the knowledge of correlation among quantitative traits is useful in two different ways. Firstly, it helps to predict the response of other characters when we select for one. The implication of positive and negative or no correlation can help in selection of suitable parents for hybridization and formulation of appropriate selection procedure for simultaneous improvement of more than one character. Secondly, information regarding the nature and extent of association of morphological characters would be helpful in developing ideal plant type in addition to the improvement of yield which is a complex character for which direct selection is not effective. For this purpose, it is important to know the association between the yield and its components as it would provide valuable information about the correlation response to selection.

In the present study, during 2016-17, significant and positive phenotypic correlation of green pod yield per plant was observed with number of pods per plant (0.421), pod weight (0.515), pod length (0.445), number of pickings (0.574) and harvesting span (0.510). Significant and negative phenotypic correlation of green pod yield per plant was found with days to 50% flowering (-0.226), days to first harvest (-0.364), pod width (-0.228) and fibre content (-0.375) (Table 16). Days to 50% flowering showed a significant and positive phenotypic correlation with days to first harvest (0.752) and protein content (0.405). A significant and negative phenotypic correlation was found with harvesting span (-0.348) and significant and negative correlation was found with pod length (-0.228), number of pickings (-0.246).

Days to first harvest was significantly and positively correlated with protein content (0.229) and fibre content (0.307). A negative and significant correlation was observed with

pod weight (-0.335), pod length (-0.370), number of pickings (-0.382) and harvesting span (-0.459). A significant and positive correlation of number of pods per plant was found with dry matter (0.254) and sugar content (0.249) while negative and significant correlation was found with pod weight (-0.383). Pod weight was significantly and positively correlated with pod length (0.517), number of pickings (0.633) and harvesting span (0.538) while negative and significant correlation was found with pod width (-0.283), dry matter (-0.290) and fibre content (-0.517). A significant and positive correlation of pod length was found with number of pickings (0.406) and harvesting span (0.334) and negative and significant correlation was found with dry matter (-0.274) and fibre content (-0.272). Significant and positive correlation of pod width was found with dry matter (0.389) while negative and significant correlation was found with number of pickings (-0.380) and harvesting span (-0.291). Number of pickings was significantly and positively correlated with harvesting span (0.785) and negative correlation was found with dry matter (-0.423) and fibre content (-0.558). Harvesting span was significantly and negatively correlated with fibre content (-0.482). Dry matter was significantly and negatively correlated with fibre content (-0.299) and protein content with sugar content (-0.217) and fibre content (-0.227).

During 2017-18, highly significant and positive phenotypic correlation of green pod yield per plant was observed with number of pods per plant (0.516), pod weight (0.418), pod length (0.454), number of pickings (0.602), harvesting span (0.607), protein content (0.204) (Table 17). Highly significant and negative phenotypic correlation of green pod yield per plant was found with dry matter (-0.250) and fibre content (-0.310). Green pod yield per plant was negatively and significantly correlated with days to first harvest (-0.155), pod width (-0.153). Days to 50% flowering showed a significant and positive phenotypic correlation with days to first harvest (0.733) and protein content (0.335). Days to 50% flowering showed a significant and negative phenotypic correlation with sugar content (-0.300) and pod length (-0.234).

A significant and negative correlation of days to first harvest was observed with pod weight (-0.278), pod length (-0.370), sugar content (-0.195) and number of pickings (-0.188). Positive correlation of days to first harvest with protein content (0.178) was found. A significant and positive correlation of number of pods per plant was found with sugar content (0.263) while negative and significant correlation was found with pod weight (-0.429) and pod length (-0.172). Pod weight was significantly and positively correlated with pod length (0.686), number of pickings (0.594) and harvesting span (0.553) while negative and significant correlation was found with pod width (-0.203), dry matter (-0.353) and fibre content (-0.402). A significant and positive correlation of pod length was found with number

of pickings (0.470) and harvesting span (0.481) while negative and significant correlation was with dry matter (-0.393) and fibre content (-0.219). Significant and positive correlation of pod width was found with dry matter (0.407) while negative and significant correlation was found with number of pickings (-0.323) and harvesting span (-0.294). Number of pickings was significantly and positively correlated with harvesting span (0.848) whereas negatively correlated with dry matter (-0.459) and fibre content (-0.527). Harvesting span was positively and significantly correlated with protein content (0.194) whereas negatively correlated with dry matter (0.374), fibre content (-0.491). Dry matter was significantly and positively correlated with fibre content (0.193). Protein content was negatively and significantly correlated with sugar content (-0.196) and fibre content (-0.331).

The pooled data analysis of both years showed that significant and positive phenotypic correlation of green pod yield per plant was observed with number of pods per plant (0.516), pod weight (0.418), pod length (0.454), number of pickings (0.602), harvesting span (0.607) and protein content (0.204). A significant and negative phenotypic correlation of green pod yield per plant was found with dry matter (-0.250) and fibre content (-0.310). Green pod yield per plant was negatively and significantly correlated with days to first harvest (-0.155), pod width (-0.153). Days to 50% flowering showed a highly significant and positive phenotypic correlation with days to first harvest (0.733) and protein content (0.335) while significant and negative phenotypic correlation was found with sugar content (-0.300) and pod length (-0.234).

A negative and highly significant correlation of days to first harvest was observed with pod weight (-0.278), pod length (-0.370), sugar content (-0.195) and number of pickings (0.188). A significant and positive correlation of number of pods per plant was found with sugar content (0.263) while negative and significant correlation was found with pod weight (-0.429) and pod length (-0.172). Pod weight was significantly and positively correlated with pod length (0.686), number of pickings (0.594) and harvesting span (0.553) while negative and significant correlation was found with pod width (-0.203), dry matter (-0.353) and fibre content (-0.402).

A significant and positive correlation of pod length was found with number of pickings (0.470) and harvesting span (0.481) and negative & significant correlation was with dry matter (-0.393) and fibre content (-0.219). Significant and positive correlation of pod width was found with dry matter (0.407) while negative and significant correlation was found with number of pickings (-0.323) and harvesting span (-0.294). Number of pickings was significantly and positively correlated with harvesting span (0.848) whereas negatively correlated with dry matter (-0.459) and fibre content (-0.527). Harvesting span was positively

**Table 16: Genotypic and phenotypic correlation among different traits in French bean (2016-17)**

Characters		Days to 50% flowering	Days to first harvest	Number of pods per plant	Pod weight	Pod length	Pod Width	Number of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre Content	Green pod yield per plant
Days to 50% flowering	G	1.000	0.722	-0.226	-0.132	-0.267	0.234	-0.275	-0.391	0.044	0.415	-0.218	0.131	-0.235
	P	1.000	0.752**	-0.188	-0.110	-0.228*	0.099	-0.246*	-0.348**	0.041	0.405**	-0.208	-0.122	-0.227*
Days to first harvest	G		1.000	-0.133	-0.451	-0.428	0.334	-0.437	-0.522	0.115	0.231	-0.088	0.325	-0.401
	P		1.000	-0.095	-0.335**	-0.370**	0.163	-0.382**	-0.460**	0.112	0.229*	-0.075	0.307**	-0.364**
Number of pods per plant	G			1.000	-0.317	-0.121	0.172	-0.285	-0.125	0.348	-0.048	0.324	0.196	0.519
	P			1.000	-0.383**	-0.047	0.172	-0.168	-0.041	0.254*	-0.050	0.249*	0.132	0.421**
Pod weight	G				1.000	0.844	-0.905	0.927	0.766	-0.413	0.138	-0.178	-0.704	0.674
	P				1.000	0.517**	-0.283**	0.633**	0.534**	-0.290**	-0.102	-0.132	-0.517**	0.515**
Pod length	G					1.000	-0.902	0.544	0.405	-0.310	0.125	0.078	-0.373	0.583
	P					1.000	-0.380**	0.406**	0.334**	-0.273*	0.099	0.066	-0.272*	0.445**
Pod width	G						1.00	-0.811	-0.550	0.622	-0.076	0.217	0.295	-0.417
	P						1.00	-0.380**	-0.291**	0.389**	-0.065	0.119	0.178	0.220
Number of pickings	G							1.000	0.880	-0.472	0.143	-0.244	-0.417	0.618
	P							1.000	0.785**	-0.423**	0.121	-0.207	-0.558**	0.574**
Harvesting span	G								1.000	-0.212	0.099	-0.169	-0.558	0.568
	P								1.000	-0.198	0.088	-0.156	-0.482**	0.510**
Dry matter	G									1.000	0.085	0.099	0.308	-0.129
	P									1.000	0.077	0.096	0.299**	-0.114
Protein content	G										1.000	-0.226	-0.235	0.179
	P										1.000	-0.219	-0.227*	0.169
Sugar content	G											1.000	0.043	-0.101
	P											1.000	0.033	-0.100
Fibre content	G												1.000	-0.404
	P												1.000	-0.375**
Green pod yield per plant	G													1.000
	P													1.000

Critical value of 'r' at 5%= 0.2119 and that at 1%= 0.2743 (\* and \*\* at 5% and 1% level of significance, respectively)

Table 17: Genotypic and phenotypic correlation among different traits in French bean (2017-18)

Characters		Days to 50% flowering	Days to first harvest	Number of pods per plant	Pod weight	Pod length	Pod Width	Number of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre Content	Green pod yield per plant
Days to 50% flowering	G	1.000	0.738	-0.050	-0.088	-0.247	-0.020	-0.096	-0.150	-0.019	0.283	-0.391	-0.067	-0.050
	P	1.000	0.725**	-0.046	-0.083	-0.238*	-0.004	-0.083	-0.131	-0.007	0.280**	-0.381**	-0.061	-0.050
Days to first harvest	G		1.000	0.109	-0.287	-0.395	0.097	-0.030	-0.151	0.132	0.152	-0.299	-0.123	-0.018
	P		1.000	0.085	-0.246*	-0.370**	0.119	-0.036	-0.139	0.142	0.146	-0.289**	-0.108	-0.022
Number of pods per plant	G			1.000	-0.463	-0.300	0.036	0.117	0.172	0.069	0.047	0.314	0.037	0.599
	P			1.000	-0.459**	-0.249*	0.024	0.066	0.113	0.024	0.041	0.276*	0.011	0.584**
Pod weight	G				1.000	0.913	-0.150	0.732	0.668	-0.456	0.145	-0.126	-0.369	0.397
	P				1.000	0.788**	-0.140	0.577**	0.568**	-0.387**	0.128	-0.119	-0.317**	0.351**
Pod length	G					1.000	-0.225	0.681	0.689	-0.510	0.118	-0.096	-0.204	0.484
	P					1.000	-0.203	0.544**	0.580**	-0.453*	0.105	-0.088	-0.184	0.462**
Pod width	G						1.00	-0.438	-0.476	0.572	-0.260	0.211	0.117	-0.103
	P						1.00	-0.254**	-0.298**	0.440**	-0.204	0.159	0.123	-0.093
Number of pickings	G							1.000	0.961	-0.581	0.368	-0.074	-0.550	0.766
	P							1.000	0.925**	-0.517**	0.334**	-0.049	-0.496**	0.641**
Harvesting span	G								1.000	-0.530	0.308	-0.063	-0.560	0.766
	P								1.000	-0.480**	0.282**	-0.055	-0.500**	0.681**
Dry matter	G									1.000	-0.067	0.172	0.148	-0.359
	P									1.000	-0.069	0.143	0.132	-0.332**
Protein content	G										1.000	-0.173	-0.446	0.244
	P										1.000	-0.175	-0.427*	0.233*
Sugar content	G											1.000	-0.002	0.042
	P											1.000	-0.022	0.039
Fibre content	G												1.000	-0.262
	P												1.000	-0.256*
Green pod yield per plant	G													1.000
	P													1.000

Critical value of 'r' at 5%= 0.2119 and that at 1%= 0.2743 (\* and \*\* at 5% and 1% level of significance, respectively)

**Table 18: Genotypic and phenotypic correlation among different traits in French bean (Pooled)**

Characters		Days to 50% flowering	Days to first harvest	Number of pods per plant	Pod weight	Pod length	Pod Width	Number of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre Content	Green pod yield per plant
Days to 50% flowering	G	1.000	0.777	-0.152	-0.113	-0.309	0.126	-0.194	-0.296	-0.047	0.363	-0.343	0.003	-0.146
	P	1.000	0.733**	-0.103	-0.094	-0.234**	0.044	-0.161*	-0.223**	0.010	0.335**	-0.300**	0.021	-0.125
Days to first harvest	G		1.000	0.009	-0.361	-0.497	0.272	-0.245	-0.373	0.159	0.212	-0.239	0.050	-0.188
	P		1.000	0.018	-0.278**	-0.370**	0.136	-0.188**	-0.262**	0.132	0.178*	-0.195**	0.063	-0.155*
No. of pods per plant	G			1.000	-0.387	-0.215	0.324	-0.049	0.035	0.189	0.004	0.299	0.093	0.583
	P			1.000	-0.429**	-0.172*	0.091	-0.045	0.049	0.103	0.002	0.263**	0.064	0.516**
Pod weight	G				1.000	0.864	-0.678	0.833	0.789	-0.470	0.137	-0.151	-0.547	.0.506
	P				1.000	0.686	-0.203**	0.594**	0.553**	-0.353**	0.116	-0.124	-0.219**	0.417**
Pod length	G					1.000	-0.707	0.670	0.645	-0.454	0.111	-0.023	-0.341	0.537
	P					1.000	-0.273**	0.470**	0.481**	-0.393**	0.102	-0.021	-0.219**	0.454**
Pod width	G						1.00	-0.695	-0.689	0.729	-0.284	0.262	0.264	-0.301
	P						1.00	-0.323**	-0.294**	0.407**	-0.134	0.138	0.151*	-0.153*
Number of pickings	G							1.000	0.970	-0.541	0.261	-0.175	-0.595	0.685
	P							1.000	0.848**	-0.459**	0.222**	-0.133	-0.527**	0.602**
Harvesting span	G								1.000	-0.396	0.212	-0.130	-0.600	0.704
	P								1.000	-0.374**	0.194*	-0.102	-0.491**	0.607**
Dry matter	G									1.000	0.007	0.177	0.253	-0.270
	P									1.000	-0.013	0.121	0.193*	-0.250**
Protein content	G										1.000	-0.204	-0.365	0.209
	P										1.000	-0.196**	-0.331**	0.204**
Sugar content	G											1.000	0.017	-0.036
	P											1.000	0.006	-0.027
Fibre content	G												1.000	-0.342
	P												1.000	-0.311**
Green pod yield per plant	G													1.000
	P													1.000

Critical value of 'r' at 5% = 0.1488 and that at 1% = 0.1947 (\* and \*\* at 5% and 1% level of significance, respectively)

and significantly correlated with protein content (0.194) whereas negatively correlated with dry matter (0.374), fibre content (-0.491). Dry matter was significantly and positively correlated with fibre content (0.193). Protein content was negatively and significantly correlated with sugar content (-0.196) and fibre content (-0.331).

The results are consistent with the findings reported by Islam *et al* (2011), Bhushan *et al* (2007), Kulaz *et al* (2013) Rai *et al* (2004), Kamaluddin and Ahmed (2013), Verma *et al* (2014), Roy *et al* (2006) and Devi *et al* (2015).

#### **4.3.2 Path coefficient analysis**

Since a correlation coefficient measures a two way association without regard causation and effect, so a correlation coefficient may not always provide a true picture. The association becomes complex when many correlated characters are affecting a particular trait. In order to get a true picture, the partitioning of correlation coefficient into direct and indirect effects become important. Path coefficient analysis determines the causal pathways of association and enables a breeder to evaluate the direct effect of one cause and its indirect effect via other causes. It amounts to a sub division of total correlation between involved characters. In the present study, the direct and indirect effects of various characters affecting total yield at genotypic and phenotypic levels were studied.

During year 2016-17, partitioning total phenotypic association between green pod yield per plant and other characters revealed that maximum direct contribution was made by number of pods per plant (0.725) followed by pod weight (0.559) and number of pickings (0.340). High positive indirect effect was found in case of harvesting span via pod weight (0.298), pod weight via number of pickings (0.215), pod length via pod weight (0.289) and harvesting span via number of pickings (0.267) (Table 19).

During 2017-18, direct contribution to green pod yield per plant was made by number of pods per plant (0.684) followed by number of pickings (0.480). Maximum indirect contribution was made by pod length via number of pickings (0.327), harvesting span via number of pickings (0.461), pod weight via number of pickings (0.351), pod length via number of pickings (0.327) and dry matter via number of pickings (-0.279) (Table 20).

In pooled analysis of both years revealed that maximum direct effect on green pod yield per plant was made by number of pods per plant (0.801) and pod weight (0.518). High indirect effect made by pod weight via number of pods per plant (-0.344), pod length via pod weight (0.356), number of pickings via pod weight (0.308), harvesting span via pod weight (0.287) and harvesting span via number of pickings (0.255) (Table 21). The present outcome is in congruous with the findings of Bhushan *et al* (2008), Salehi *et al* (2010), Pawar and Prajapati (2013), Sidika *et al* (2013), Ravinaik *et al* (2014) and Alemu *et al* (2017).

**Table 19: Direct and indirect values of phenotypic path coefficient for various characters of French bean (2016-17)**

S. No.	Characters	Days to 50% flowering	Days to first harvest	No. of pods per plant	Pod weight	Pod length	Pod width	No. of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre content
1.	Days to 50% Flowering	<b>-0.012</b>	-0.009	0.002	0.001	0.003	-0.001	0.003	0.004	-0.001	-0.005	0.003	-0.002
2.	Days to First harvest	-0.010	<b>-0.013</b>	0.001	0.004	0.005	-0.002	0.005	0.006	-0.002	-0.003	0.001	-0.004
3.	No. of pods per plant	-0.136	-0.069	<b>0.725</b>	-0.278	-0.034	0.125	-0.122	-0.030	0.185	-0.036	0.181	0.096
4.	Pod weight	-0.062	-0.187	-0.214	<b>0.559</b>	0.289	-0.158	0.354	0.298	-0.162	0.057	-0.074	-0.289
5.	Pod length	-0.016	-0.026	-0.003	0.036	<b>0.071</b>	-0.026	0.029	0.024	-0.019	0.007	0.005	-0.019
6.	Pod width	-0.005	-0.008	-0.008	0.013	0.017	<b>-0.047</b>	0.018	0.014	-0.018	0.003	-0.006	-0.008
7.	No. of pickings	-0.084	-0.130	-0.057	0.215	0.138	-0.129	<b>0.340</b>	0.267	-0.144	0.041	-0.070	-0.190
8.	Harvesting span	0.031	0.041	0.004	-0.048	-0.030	0.026	-0.071	<b>-0.090</b>	0.018	-0.008	0.014	0.043
9.	Dry matter	0.001	0.004	0.008	-0.009	-0.009	0.013	-0.014	-0.006	<b>0.033</b>	0.003	0.003	0.010
10.	Protein content	0.034	0.019	-0.004	0.008	0.008	-0.005	0.010	0.007	0.006	<b>0.083</b>	-0.018	-0.019
11.	Sugar content	0.029	0.010	-0.035	0.018	-0.009	-0.017	0.029	0.022	-0.013	0.030	<b>-0.139</b>	-0.005
12.	Fibre content	0.001	0.003	0.002	-0.006	-0.003	0.002	-0.006	-0.005	0.003	-0.003	0.000	<b>0.011</b>
13.	Green pod yield per plant	-0.227	-0.364	0.421	0.515*	0.445*	-0.220	0.574*	0.510*	-0.114	0.170	-0.010	-0.375

Bold printed figures show direct effect of various characters on green pod yield

Residual effect= 0.4340

**Table 20: Direct and indirect values of phenotypic path coefficient for various characters of French bean (2017-18)**

S. No.	Characters	Days to 50% flowering	Days to first harvest	No. of pods per plant	Pod weight	Pod length	Pod width	No. of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre content
1.	<b>Days to 50% flowering</b>	<b>0.141</b>	0.104	-0.007	-0.012	-0.035	-0.003	-0.013	-0.021	-0.003	0.040	-0.055	-0.009
2.	<b>Days to first harvest</b>	-0.057	<b>-0.078</b>	-0.008	0.022	0.031	-0.008	0.002	0.012	-0.010	-0.012	0.023	0.010
3.	<b>No. of pods per plant</b>	-0.034	0.075	<b>0.684</b>	-0.317	-0.205	0.025	0.080	0.118	0.047	0.032	0.215	0.025
4.	<b>Pod weight</b>	-0.008	-0.027	-0.044	<b>0.095</b>	0.087	-0.014	0.070	0.064	-0.043	0.014	-0.012	-0.035
5.	<b>Pod length</b>	-0.065	-0.104	-0.079	0.241	<b>0.264</b>	-0.059	0.180	0.182	-0.135	0.031	-0.025	-0.054
6.	<b>Pod width</b>	-0.005	0.023	0.009	-0.036	-0.054	<b>0.240</b>	-0.105	-0.114	0.137	-0.062	0.051	0.028
7.	<b>No. of pickings</b>	-0.046	-0.015	0.056	0.351	0.327	-0.210	<b>0.480</b>	0.461	-0.279	0.177	-0.035	-0.264
8.	<b>Harvesting span</b>	-0.015	-0.015	0.018	0.069	0.071	-0.049	0.099	<b>0.103</b>	-0.054	0.032	-0.006	-0.057
9.	<b>Dry matter</b>	0.000	-0.002	-0.001	0.007	0.008	-0.009	0.009	0.008	<b>-0.015</b>	0.001	-0.003	-0.002
10.	<b>Protein content</b>	0.006	0.003	0.001	0.003	0.003	-0.006	0.008	0.007	-0.001	<b>0.021</b>	-0.004	-0.010
11.	<b>Sugar content</b>	0.042	0.032	-0.033	0.013	0.010	-0.022	0.008	0.007	-0.018	0.018	<b>-0.106</b>	0.000
12.	<b>Fibre content</b>	-0.007	-0.013	0.004	-0.039	-0.022	0.012	-0.058	-0.059	0.016	-0.047	0.000	<b>0.106</b>
13.	<b>Green pod yield per plant</b>	-0.050	-0.018	0.599*	0.398*	0.484*	-0.103	0.759*	0.766*	-0.359*	0.244	0.042	-0.262

Bold printed figures show direct effect of various characters on green pod yield

Residual effect= 0.3186

**Table 21: Direct and indirect values of phenotypic path coefficient for various characters of French bean (Pooled)**

S. No	Characters	Days to 50% flowering	Days to first harvest	No. of pods per plant	Pod weight	Pod length	Pod width	No. of pickings	Harvesting span	Dry matter	Protein content	Sugar content	Fibre content
1.	Days to 50% flowering	<b>0.004</b>	0.003	0.000	0.000	-0.001	0.000	-0.001	-0.001	0.000	0.001	-0.001	0.000
2.	Days to first harvest	0.024	<b>0.033</b>	0.001	-0.009	-0.012	0.005	-0.006	-0.009	0.004	0.006	-0.006	0.002
3.	No. of pods per plant	-0.083	0.015	<b>0.801</b>	-0.344	-0.138	0.073	-0.036	0.040	0.082	0.001	0.210	0.051
4.	Pod weight	-0.049	-0.144	-0.223	<b>0.518</b>	0.356	-0.105	0.308	0.287	-0.183	0.060	-0.064	-0.208
5.	Pod length	-0.031	-0.049	-0.023	0.091	<b>0.133</b>	-0.036	0.062	0.064	-0.052	0.014	-0.003	-0.029
6.	Pod width	0.000	0.001	0.000	-0.001	-0.001	<b>0.005</b>	-0.002	-0.001	0.002	-0.001	0.001	0.001
7.	No. of pickings	-0.048	-0.057	-0.014	0.179	0.141	-0.097	<b>0.301</b>	0.255	-0.138	0.067	-0.040	-0.159
8.	Harvesting span	0.005	0.005	-0.001	-0.011	-0.010	0.006	-0.017	<b>-0.020</b>	0.008	-0.004	0.002	0.010
9.	Dry matter	0.000	0.005	0.004	-0.013	-0.014	0.015	-0.017	-0.013	<b>0.036</b>	0.000	0.004	0.007
10.	Protein content	0.016	0.008	0.000	0.005	0.005	-0.006	0.010	0.009	-0.001	<b>0.046</b>	-0.009	-0.015
11.	Sugar content	0.036	0.024	-0.032	0.015	0.003	-0.017	0.016	0.012	-0.015	0.024	<b>-0.121</b>	-0.001
12.	Fibre content	0.001	0.002	0.002	-0.012	-0.007	0.005	-0.016	-0.015	0.006	-0.010	0.000	<b>0.031</b>
13.	Green pod yield per plant	-0.125	-0.155	0.516*	0.418*	0.454*	-0.153	0.602*	0.607*	-0.250	0.204	-0.027	-0.310

Bold printed figures show direct effect of various characters on green pod yield

Residual effect= 0.392

## CHAPTER V

### SUMMARY

The present investigation entitled ‘Assessment of genetic potential of French bean (*Phaseolus vulgaris* L.) genotypes in poly-net house’ was undertaken at Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during 2016-17 and 2017-18. The objective of the study was to determine the genetic potential of French bean genotypes under poly net house conditions.

In the experiment on assessment of genetic potential of French bean genotypes, 29 genotypes were collected from various sources and were sown during winter season of 2016-17 and 2017-18 in a Randomized Complete Block Design (RCBD) with three replications. The analysis of variance revealed that all the genotypes were significantly different in treatments for all characters. The observations were recorded on all the genotypes for various yield and quality traits viz. days to 50% flowering, days to first harvest, number of pods per plant, pod weight (g), pod length (cm), pod width (cm), green pod yield per plant (g), number of pickings, harvesting span (days), dry matter (%), protein content (%), sugar content (%) and fibre content (%). All the genotypes were found to be significantly different for all the traits under study. The data revealed that FBK-10 recorded least days to 50% flowering and was observed to be early yielder as it gives first picking in 105.50 days. The maximum number of pods per plant was recorded in genotype Star-1 (157.17), pod weight in FBB Var-1 (7.54 g) and pod length in Kentucky Blue (15.13 cm). Maximum number of pickings were recorded in Lakshmi (10.00) with harvesting span of 60 days. Regarding quality parameters, maximum dry matter (13.87%) was recorded in FBK-13, protein content (9.67%) in FBK-1, sugar content (9.67%) in FBK-5 and minimum fibre content (0.69%) was recorded in FBK-12. The green pod yield per plant was found to be high in Lakshmi (992.33 g), Star-1 (955.50 g), FBK-4 (911.17 g), AVT Var-3 (908.50 g), Kentucky Blue (856.17 g) and FBK-1 (842.67 g) as compared to check Kentucky Wonder (793.33 g) which may be due to more number of pods per plant, pod weight, pod length and more number of pickings in these genotypes.

Genetic variability study revealed that the phenotypic coefficient of variation (PCV) was found to be higher than their respective genotypic coefficient of variation (GCV) for all the traits which showed the influence of environment on these traits. However, there were very narrow differences between phenotypic and genotypic coefficient of variation for most of characters, indicating low environmental influence in expression of these characters which implies that phenotypic variability is a reliable measure of genotypic variability. PCV was the highest for green pod yield per plant (25.16%) followed by protein content (21.00%), number of pickings (20.58%) and sugar content (20.26%). Selection is preferred when a

major proportion of variation is heritable variation. The high heritability was recorded for all the traits except pod width which makes selection effective for improving these characters. The selection only on the heritable basis is not effective criteria for the best genotypes, however the selection based on heritability along with genetic advance as per cent mean is more effective. Genetic advance in such cases gives good idea for the actual position. Improvement in the mean genotypic value of selected families over base population is known as genetic advance. Moderate to high heritability coupled with high genetic advance was recorded for all traits except for pod width. The high heritability along with high genetic advance showed the presence of additive gene action which indicated that selection should be performed for improvement of these characters.

The correlation measures the relationship between various plant traits and determines the component characters on which selection can be based for genetic improvement in yield. The correlation analysis revealed that green pod yield per plant is positively and significantly related to number of pods per plant, pod weight, pod length, number of pickings and harvesting span at both genotypic and phenotypic levels. Path analysis studies direct effect of one cause and its indirect effect via other causes. Path analysis study revealed that pod weight, number of pods per plant, number of pickings and harvesting span had maximum direct effect on green pod yield per plant. The above characters which had maximum positive direct effect on green pod yield were also positively correlated with yield and thus selection for these traits will be effective for improving the total green pod yield. Therefore, from the present study, it has been concluded that genotypes Lakshmi, Star-1, FBK-4, AVT Var-3, Kentucky Blue and FBK-1 were found to be promising for yield and yield attributing traits.

## REFERENCES

- Alemu Y, Alamirew S and Dessalegn L (2017) Genetic variability in snap bean (*Phaseolus vulgaris* L.) genotypes in central rift valley of Ethiopia. *Int J Plant Breeding Genetics* **7**: 124-31.
- Al-Jibouri H A, Millar P A and Robinson H F (1958) Genotypic and environment variance and covariances in an upland cotton cross of interspecific origin. *Agron J* **50**: 633-36.
- Allard R W (1960) *Principles of Plant Breeding*. pp. 485. John Wiley and Sons, Inc, New York, London.
- Andrea E M, Alejandra M E, Pamela C V, David L and Sebastian L A F (2009) Relationships among agronomic traits and seed yield in Pea. *J Basic App Sci* **20**: 1-8.
- Angadi P K, Patil M G and Angadi A (2012) Correlation studies in French bean (*Phaseolus vulgaris* L.). *Asian J Hort* **7**: 574-78.
- Anonymous (2017) National Horticulture Board, Ministry of Agriculture, Government of India. [www.nhb.gov.in](http://www.nhb.gov.in)
- Arunga E E, Kinyua M, Ochuodho J and Chepkoech E (2015) Genetic diversity of determinate French beans grown in Kenya based on morpho-agronomic and simple sequence repeat variation. *J Plant Breeding Crop Sci* **7**: 240-50.
- Asati B S and Singh A K (2008) Genetic components studies in French bean (*Phaseolus vulgaris* L.). *New Agriculturist* **19**: 117-23.
- Bendale V W, Topare S S, Bhave R G, Mehta J K and Madav R R (2004) Genetic analysis on yield and yield components in lablab bean (*Lablab purpureus* L. Sweet). *Orissa J Hort* **32**: 99-101.
- Bhushan K B, Jadli S, Verma O and Goswami A K (2008) Plant characters, correlation and path coefficient analysis of seed yield in exotic French bean germplasm. *Inter J Agri Sci* **4**: 667-69.
- Biswas M S, Hassan J and Hossain M M (2010) Assessment of genetic diversity in French bean (*Phaseolus vulgaris* L.) based on RAPD marker. *African J Biotech* **9**: 5073-77.
- Boros L, Wawer A and Borucka K (2014) Morphological, phenological and agronomical characterization of variability among common bean (*Phaseolus vulgaris* L.) local populations for plant genetic resources: Polish Genebank. *J Hort Res* **22**: 123-30.
- Burton G W and Devane E H (1953) Estimating heritability in tall Fescue from replicated clonal material. *Agron J* **45**: 478-81.
- Chadha S, Sharma R, Chaudhary D R and Vidyasagar (2008) Genetic variability studies in summer pea under cold desert areas of North-Western Himalayas. *Agricultural Sci Digest* **28**: 10-13.
- Chaudhary D K and Sharma R R (2003) Genetic variability, correlation and path analysis for green pod yield and its components in garden pea. *Indian J Hort* **60**: 251-56.
- Dahiya A, Sharma S K, Singh S P and Luthra O P (2006) Path analysis of seed yield components in French bean (*Phaseolus vulgaris* L.). *Crop res* **7**: 255-57.

- Devi J, Sharma A and Santra P (2012) Genetic variability and character association studies in French bean (*Phaseolus vulgaris* L.) under North–Western Himalayas. *J Crop Weed* **8**: 65-69.
- Devi J, Sharma A, Singh Y, Katoch V and Sharma K C (2015) Genetic variability and character association studies in French bean (*Phaseolus vulgaris* L.) under North-Western Himalayas. *Int J Legume Res* **10**: 149-56.
- Dewey D R and Lu K H (1959) A correlation and path coefficient analysis of components crested wheat grass seed production. *Agron J* **51**: 515-18.
- Dhaliwal M S (2012) *Handbook of Vegetable Crop*. **2**: 261 Kalyani Publishers, New Delhi.
- Dhall R K (2018) Punjab Kheera-1: A seedless variety of cucumber for poly-net house cultivation. *Hort News Letter* **14**: 9-12.
- Dubois M, Gilles K A, Hamilton J K, Robers P A and Smith F (1956) Colorimetric method for determination of sugars. *Anal Chem* **28**: 350-56.
- Duke J A (1981) *Handbook of legumes of world economic importance*. New York, USA/London, UK, pp. 195-200.
- Dursun A (2007) Variability, heritability and correlation studies in bean (*Phaseolus vulgaris* L.) genotypes. *World J Agri Sci* **3**: 12-16.
- Fikreselassie M (2012) Variability, heritability and association of some morpho-agronomic traits in field pea (*Pisum sativum* L.) genotypes. *Pakistan J Biological Sci* **15**: 358-66.
- Georgieva N, Nikolova I, Kosev V (2016) Evaluation of genetic divergence and heritability in pea (*Pisum sativum* L.). *J Bio Sci Biotech* **5**: 61-67.
- Gomez K A and Gomez A A (1984) *Statistical Procedure for Agricultural Research*. John Wiley and Sons, New York, pp. 680-81.
- Guleria S, Chongtham N and Dua S (2009) Genetic variability, correlation and path analysis studies in pea (*Pisum sativum* L.). *Crop Res* **38**: 179-83.
- Islam M S, Rahman M M and Mian M A K (2011) Genetic variability, heritability and correlation study in hyacinth bean. *Bangladesh J Agri Res* **36**: 351-56.
- Johnson H W, Robinson H F and Comstock R E (1955) Estimates of genetic and environmental variability in soybean. *Agron J* **47**: 314-18.
- Junaif W N, Khan K P, Hussain S H, Jabeen N K and Ummiyah H M (2010) Genetic variability in dwarf French bean (*Phaseolus vulgaris* L.). *Asian J Horti* **5**: 117-18.
- Kamaluddin and Shahid A (2011) Variability, correlation and path analysis for seed yield and yield related traits in common beans. *Indian J Hort* **68**: 61-5.
- Karasu A and Oz M (2010) A study of coefficient analysis and association between agronomical characters in Dry bean (*Phaseolus vulgaris* L.). *J Agri Sci* **16**: 203-11.
- Kujur P K, Bahadur V and Pankaj P (2017) Correlation and path analysis study in Dolichos bBean (*Lablab purpureus* L.). *Int J Curr Microbiol App Sci* **6**: 2228-35.

- Kulkarni P S, Musmade A M, Bhalekar M N and Kabalkar D V (2014) Genetic divergence analysis in French bean (*Phaseolus vulgaris* L.). *Annals Agri Bio Res* **19**: 117-20.
- Kumar B (2008) Variability, heritability and genetic advance in pea (*Pisum sativum* L.). *Inter J Plant Sci* **3**: 211-12.
- Kumar P A, Reddy R, Pandravada V S K, Durga C R and Chaitanya V (2014) Genetic variability, heritability and genetic advance in pole- type French bean. *Plant Archives* **14**: 569-73.
- Kumar P, Partap P S and Rana M K (2004) Correlation studies in garden pea (*Pisum sativum* L.). *Haryana J Hort Sci* **33**: 243-45.
- Kumar P, Patil A and Angadi M G A (2012) Path coefficient analysis studies in French bean. *Asian J Hort* **7**: 133-36.
- Kumar V, Ram R B, Rajvanshi S K and Dohre S (2015) Study on genetic variability, heritability and genetic advance for yield and yield attributing characters in Cluster bean [*Cyamopsis tetragonoloba* (L). Taub.]. *Inter J Agri Sci Res* **5**: 235-46.
- Lad D B, Longmei N, Borle U M (2017) Studies on genetic variability, association of characters and path analysis in French bean (*Phaseolus vulgaris* L.). *Int J Pure App Biosci* **5**: 1065-69.
- Manivannan A and Anandakumar C R (2013) Genetic variability, character association and path analysis in Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub). *J Food Legumes* **26**: 34-37.
- Meena J and Dhillon T S (2014) Studies on performance of French bean genotypes for yield and quality traits under protected conditions. *Tropentag* **1**: 17-19.
- Meena J, Dhillon T S, Meena A and Singh K K (2017) Studies on performance of French bean (*Phaseolus vulgaris* L.) genotypes for yield and quality traits under protected conditions. *Plant Archives* **17**: 615-19.
- Mehra R, Tikle A N, Saxena A, Munjal A, Khandia R and Singh M (2016) Correlation path coefficient and genetic diversity in Blackgram (*Vigna mungo* (L.) Hepper). *Int Res J Plant Sci* **7**: 1-11.
- Miller P A, Williams J E, Robinson H F and Comstock R E (1958) Estimates of variance and co-variance in upland cotton and their implications in selection. *Agron J* **50**: 126-31.
- Nawab N N, Subhani G M, Khalid M, Qamar S and Akhtar S (2008) Genetic variability, correlation and path analysis studies in garden pea (*Pisum sativum* L.). *J Agri Res* **46**: 333-40.
- Negahi A, Bihamta M R, Negahi Z and Allidoust M (2014) Evaluation of Genetic Variation of Some Agronomical and Morphological Traits in Iranian and Exotic Common bean (*Phaseolus vulgaris* L.). *Agri Commun* **2**: 22-26.
- Noor F, Hossain F and Ara U (2014) Screening of French bean (*Phaseolus vulgaris* L.) genotypes for high yield potential. *Bangladesh J Sci Ind Res* **49**: 227-32.

- Pandey Y R, Gautam D M, Thapa R B, Sharma M D and Paudyal K P (2011) Evaluation of pole-type French bean genotypes in the mid hills of western Nepal. *J Nepal Agri Res* **11**: 80-86.
- Parmar A M, Singh A P, Dhillon N P S and Jamwal M (2013) Genetic variability studies for morphological and yield traits in Dolichos bean (*Lablab purpureus* L.). *World J Agri Sci* **9**: 24-8.
- Pawar R M and Prajapati R M (2013) Genetic variability, correlation and path analysis in Indian bean (*Lablab purpureus* L. Sweet). *Int J Agri Sci* **9**: 615-19.
- Prakash J and Ram R B (2014) Genetic variability, correlation and path analysis for seed yield and yield related traits in French bean (*Phaseolus vulgaris* L.) under Lucknow conditions. *Int J Innov Sci Engg Tech* **12**: 110-15.
- Prakash J, Ram R B, Meena M L (2015) Genetic variation and characters interrelationship studies for quantitative and qualitative traits in French bean (*Phaseolus vulgaris* L.) under Lucknow conditions. *Legume Res* **38**: 425-33.
- Prasanth K, Sreelathakumary I and Celine V A (2016) Correlation and path analysis studies for green pod yield and component characters in winged bean (*Phosphocarpus tetragonolobus* L.). *The Bioscan* **11**: 977-80.
- Rafi S A and Nath U K (2004) Variability, heritability, genetic advance and relationship of yield and yield contributing characters in dry Bean (*Phaseolus vulgaris* L.). *J Bio Sci* **4**: 157-59.
- Rai N, Asati B S, Singh A K and Yadav D S (2006) Genetic variability, character association and path coefficient study in pole-type French bean. *Indian J Hort* **63**: 188-91.
- Rai P S and Dharmatti P R (2014) Correlation and path analysis for cluster bean vegetable pod yield. *The Bioscan* **9**: 811-14.
- Ravinaik K, Hanchinamani C N, Patil M G and Imamsahebi S J (2014) Correlation and path co-efficient analysis in dolichos bean (*Dolichos lablab* L.) genotypes. *Asian J Hort* **9**: 396-99.
- Sadeghi A, Cheghamirza K and Dorri H R (2011) The study of morpho-agronomic traits relationship in common bean (*Phaseolus vulgaris* L.). *Biharean Biologist* **5**: 102-108.
- Saleh S M, Shleel S M A and Hadid A F A (2012) Prediction and adaptation of dry bean yield under climate change conditions. *Res J Agri and Bio Sci* **8**: 147-53.
- Salehi M, Faramarzi A and Mohebalipour N (2010) Evaluation of different effective traits on seed yield of common bean (*Phaseolus vulgaris* L.) with path analysis. *American Eurasian J Agr and Env Sci* **9**: 52-54.
- Santhi V P, Rajai P, Anita B and Selvaraj N (2015) Evaluation of French beans (*Phaseolus vulgaris* L.) bush type at mid and higher elevations of Nilgiris. *Asian J Hort* **10**: 100-04.
- Sardana S, Mahajan R K, Gautam N K and Ram B (2007) Genetic variability in pea (*Pisum sativum* L.) germplasm for utilization. *J Breeding and Genetics* **39**: 31-41.

- Shahid A and Kamaluddin (2013) Correlation and path analysis for agro-morphological traits in rajmash beans under Baramulla- Kashmir region. *African J Agri Res* **8**: 2027-32.
- Sharifi P (2014) Genetic variation for seed yield and some of agro-morphological traits in Faba bean (*Vicia faba* L.) genotypes. *Acta Agriculturae Slovenica* **105**: 73-83.
- Sharma A, Pathania N K, Kalia P (2006) Horticultural evaluation of garden pea germplasm under humid sub-temperate environment of northwestern Himalaya. *Indian J Plant Genetic Resour* **19**: 87-90.
- Siddika A, Aminul Islam A K M, Golam Rasul M, Abdula K M and Ahmad J U (2013) Genetic variability in advanced generation of vegetable pea (*Pisum sativum* L.) *Int J Plant Breeding* **7**: 124-28.
- Singh A K and Mir M S (2005) Genetic variability, heritability and genetic advance in pea (*Pisum sativum* L.) under cold arid region of Ladakh. *Env Eco* **23**: 445-49.
- Singh A K, Singh K P and Singh B K (2007) Evaluation and screening of French bean genotypes for high yield. *Haryana J Hort Sci* **36**: 54-55.
- Singh B K, Deka B C and Ramakrishna Y (2014) Genetic variability, heritability and interrelationships in pole- type French bean (*Phaseolus vulgaris* L.) *Proc Natl Acad Sci India B Biol Sci* **84**: 587-92.
- Singh B, Goswami A and Srivastava D K (2014) Study of genetic variability, heritability and genetic advance in table Pea (*Pisum sativum* spp. *hortense* L.). *Progressive Agri* **14**: 280-84.
- Singh D N, Sivakumar R and Bhanja P K (2011) Variability and character association in new genotypes of French bean. *Env Eco* **29**: 1811-13.
- Singh J D and Singh I P (2006) Genetic divergence in advanced genotypes for grain yield in field pea (*Pisum sativum* L.). *Legume Res* **29**: 301-03.
- Singh V, Singh A K, Moharana D P, Singh B, Jaiswal D K and Singh D K (2017) Assessment of quantitative differences among diverse genotypes of French bean (*Phaseolus vulgaris* L.) for yield and yield attributing traits. *J Pharmaco Phytochem* **6**: 1557-59.
- Singh Y, Sharma M and Sharma A (2009) Genetic variation, association of characters and their direct and indirect contributions for improvement in chilli peppers. *Int J Veg Sci* **15**: 340-68.
- Sofi P A, Zargar M Y, Debouck D, Graner A (2011) Evaluation of common bean (*Phaseolus vulgaris* L.) germplasm under temperate conditions of Kashmir valley. *J Phytol* **3**: 47-52.
- Topwal M and Gaur G (2014) Studies on genetic variability in different genotypes of French bean (*Phaseolus vulgaris* L.). *Int J Life Sci Scienti Res* **2**: 219-21.
- Verma A K, Jyothi K U and Rao A V D (2014) Genetic variability, heritability and genetic advance studies in Dolichos bean (*Lablab purpureus* L.) genotypes. *Electronic J Plant Breeding* **5**: 272-76.

Verma V K, Jha A K, Pandey A, Kumar A, Choudhury P and Swer T L (2014) Genetic divergence path coefficient and cluster analysis of French bean (*Phaseolus vulgaris* L.) genotypes. *Indian J Agri Sci* **84**: 925-30.

Walling B and Chaturvedi H P (2014) Genetic variability, character association and path coefficient analysis in French bean (*Phaseolus vulgaris* L.) genotypes of Nagaland. *Indian Res J Genetics Biotech* **2**: 397-401.

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